SCIENTIFIC AMERICAN
No. SUPPLEMENT 789

Scientific American Supplement, Vol. XXXI. No. 789. NEW YORK, FEBRUARY 14, 1891. Scientific American Supplement, $5 a year.
Scientific American, established 1845. Scientific American and Supplement, $7 a year.

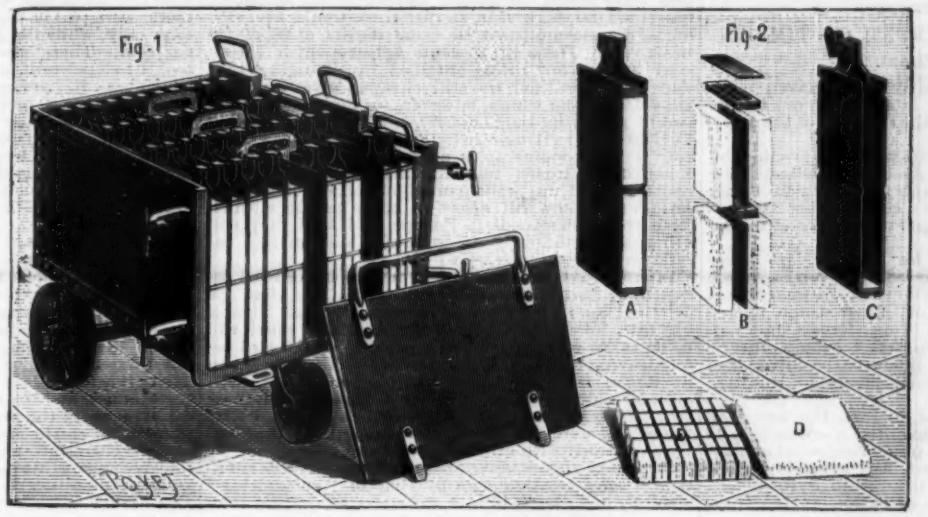
MANUFACTURE OF SUGAR IN TABLETS.

THE refining of raw sugar has, within a few months, undergone a certain transformation, the object of which is to adapt the final product to the taste of the consumer. The conical form of loaf sugar, as well known, does not favor its being cut up into regular pieces. Sawing and breaking are accompanied with a waste whose value is far from being trivial. Moreover, the crust melts slowly and with difficulty.

An endeavor has been made to obtain refined sugar in a form that shall permit of the sawing and breaking of it without causing much waste. The researches have been especially directed toward the partitioning of the turbines employed in the turbining of the boiled masses. There have already been obtained (in Germany especially), in this direction, certain results for the direct preparation of sugar in tablets, that they may afterward be cut up into small pieces. But this process is objectionable in that, in order to overcome the difficulty of emptying the moulds, there has been given to the tablets a trapezoidal form in which sawing and breaking produce pieces that are not exactly like one another and are difficult to pack. Mr. H. Vivien has succeeded in obtaining products of great purity and of a very regular shape. His process consists in running the boiled mass (obtained by concentration in a vacuum and the boiling of sirup in grains) into special moulds that permit of obtaining tablets having the form of a perfect parallelopipedon. As the opposite faces are consequently parallel with each other, there can be no loss in sawing, such as occurs with sugar in loaves. The thickness of the tablet corresponds to the length of the piece sawed, and can be of any dimensions desired. The mould devised (and recently improved) by Mr. Vivien consists of two parallel galvanized steel plates (Fig. 2), bent at right angles at one of their extremities, so that they can be riveted to a flat iron bottom. At the top the plates are provided with an open spring formed of two flexible, curved pieces. One of these is provided with a clasp that serves to unite the two parts of the spring, and, consequently, during the work, to keep the sides at the proper distance apart for obtaining parallelopipedon-shaped tablets. Upon throwing back the clasp, the sides of the mould, by reason of their elasticity, tend to recede from each other, and permit the tablets to be easily removed. At the center and top, the sides are provided internally with horizontal ribs designed to support partitions separated by a strip of metal at the center, and grooved at the sides. In this way the partitions enter or leave the mould by sliding. In their faces there are channels, in which slide separable steel plates, placed vertically. The mould is thus divided into four compartments, that permit of obtaining the same number of tablets of sugar that are perfectly regular.

The manipulations relative to the running of the saccharine material into the moulds are effected in a special iron plate trundle (Fig. 1), three of the sides of which are assembled by angle irons so as to render them hermetical. The fourth side is movable, and is provided with a maneuvering handle. This gate is in front of the vehicle. When closed, it is pressed against a bearing of rubber held in a groove formed in the edges of the box. Binding screws, whose nuts are jointed to curved supports, make this joint tight.

The moulds are arranged side by side, in rows, separated from each other by movable galvanized iron plates provided with handles, and are pressed against each other by wooden wedges, that extend to the bottom of the trundle. The vehicle thus loaded is placed under the boiling apparatus in order to receive the saccharine material, which fills all the moulds by passing through the apertures in the transverse partitions. The whole is left to cool for a few hours, and until crystallization and hardening of the mass has taken place. The trundle is then opened, and the moulds are emptied by means of a solid plate that is slid between the parts of the spring and the upper perforated partition. The moulds are then ready to be placed in a centrifugal apparatus, wherein the operation of refining is finished.



SUGAR TABLETS.

FIG. 1.—Wagon for Carrying Moulds. FIG. 2.—Tablet Moulds: A, mould for two tablets; B, mould for four tablets, taken apart; C, mould for two tablets, empty; D, E, tablets entire and sawed into cubes.

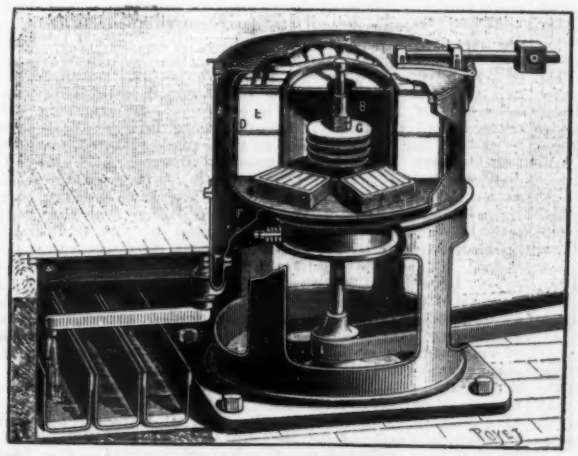


FIG. 3.—CENTRIFUGAL APPARATUS.

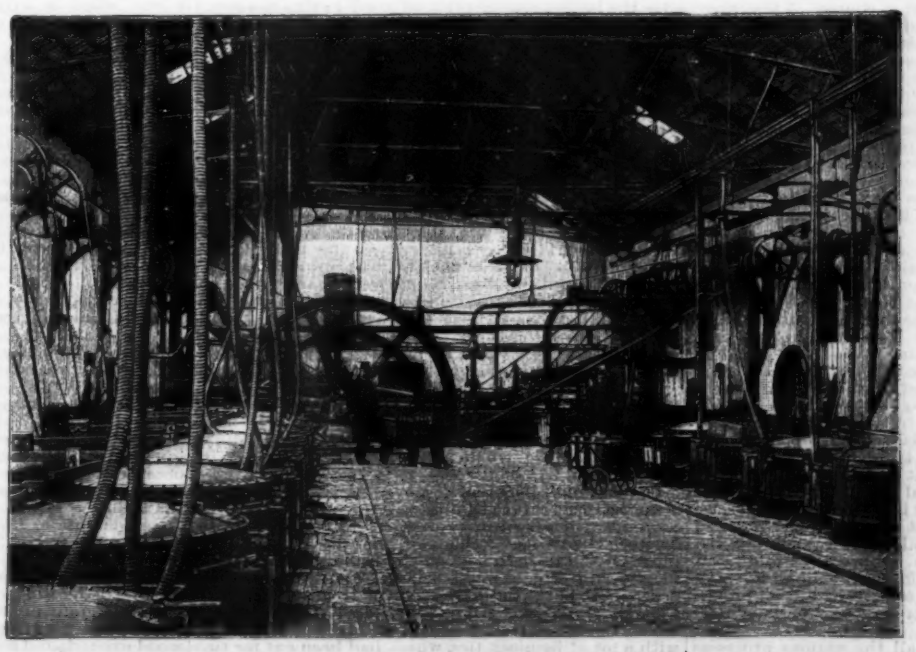


FIG. 4.—INSTALLATION OF SUGAR REFINING APPARATUS AT BARBERY.

This apparatus (Fig. 3) consists of an iron plate drum, A, provided with an internal crown, B, which forms with it an annular space, which is divided into six or eight compartments for the reception of the moulds. Wedges and tightening apparatus, E, keep these moulds vertical and firmly in place. A movable cap, C, covers the apparatus and is closed with a bolt. In the center of the drum there is an equilibrium regulator, of which the disks move around a shaft, H, that receives its motion at the bottom through an intermediate transmission and a pulley, I, keyed to the shaft. The latter is provided with a steel pivot mounted in a swivel step bearing. Through the action of rotation, the disks are moved in such a way as to bring the center of gravity into the axis of the turbine and prevent the shaking due to an inequality in the charge of the tablets.

Upon the drum being given a sufficiently rapid revolution, the sirup that surrounds the crystals of sugar is expelled through the centrifugal force developed, traverses perforated bronze plates, D, placed symmetrically in the drum, rises above the edge of the drum, runs into the receptacle, F, and then into reservoirs to await ulterior operations. This first operation performed, the apparatus is stopped in order to effect the first clarification in the drum by the introduction, through piping arranged for the purpose, of some yellow sugar sirup into the annular part in which the moulds are inclosed. This sirup impregnates the sugar contained in the latter. After a lapse of about eight or ten minutes, a cock at the bottom of the drum is opened in order to allow of the outflow of the small amount of non-absorbed sirup into a conduit that leads it to the sirup reservoir. The turbine is set in operation again in order to expel the sirup, and then the moulds are taken out and placed in a small box situated near each turbine, and in which a second clarification is effected with white sugar sirup. The moulds are afterward put back into the apparatus, wherein the operation of refining is finished.

The arrangement adopted permits of the products being allowed to remain in the white sugar sirup for nearly an hour, if it is desired, without delaying the work in any way. The saccharine mass is thus forcedly and regularly impregnated with the saturated solution of sugar, and the purification of it by centrifugal force is rapidly effected. This point is important, especially when we are working cane sugars or those of low titration, which give products that are more or less pure and colored. Mr. Vivien's improved mould is particularly advantageous in that it permits of obtaining tablets of sugar of slight thickness that can thus be cut up, not only into the regular pieces of the form known to the French consumer, but also into the small cubes that are now demanded for export, especially in England.

Our refiners will certainly be able to appreciate the advantages that are offered by this essentially French process of refining, which permits of rapidly obtaining tablets that it is only necessary to carry to the stove and al-

low to remain for a few hours in order to finish the desiccation. The daily production of one turbine may reach 8,000 kilogrammes. The rendering in sugar per 100 kilogrammes of boiled and turbinated material is from 70 to 72 per cent., and the rendering in regular pieces derived from the sawed and broken tablets is about 80 per cent., while with ordinary loaves of sugar scarcely 60 per cent. is exceeded.

If need be, the sugar can be sold in entire tablets, D (Fig. 2), but it is preferable to cut it up with a circular saw into slices, and then to reduce these with a breaking machine into regular pieces, which are delivered to the trade arranged in wooden cases or cardboard boxes.

It is of interest to sum up the advantages offered by the manufacture of sugar such as we have just described. In addition to the very convenient form of the cubical pieces and the rapidity of manufacture, we find a notable saving in manual labor and in clarifying material, with an increase in rendering. Finally, as the refining is more rapid, there is less material in course of manufacture, and this leads to a reduction of capital and of insurance premiums.—*La Nature.*

PRESERVATIVE TREATMENT OF TIMBER.

By OCTAVE CHANUTE.

WHAT follows is a report nearly in full, given in the *Railroad Gazette*, of a lecture lately delivered by Mr. Octave Chanute, C.E., before the students of the Rensselaer Polytechnic Institute:

I shall endeavor to interest you this evening by talking to you on a subject concerning which little has yet been done in this country, but which in my judgment is destined to have a considerable application—I mean the artificial preparation of wood to prevent its decay. . . .

The prices of railroad ties, for instance, are lower now, in 1890, than they were in 1882. Nevertheless, we are consuming at present at least twice the quantity of wood and twice the quantity of timber which is produced in the ordinary growth of our forests, and timber is sure to rise. It is certain that economy must be practiced, and that which is likely to be introduced first is the resorting to artificial means to lengthen its life.

Impressed with these views in 1880, the American Society of Civil Engineers appointed a committee to report on the best methods of preserving wood against decay. That committee spent five years in the investigation, and it reported in 1885 in a pamphlet, which attracted considerable attention at the time, and which it is hoped will lead eventually to economical results in this country. I had the honor of being a member of that committee, became very much interested in the subject, and I have since made it a business to promote the artificial preparation of wood, and to do what missionary work I could toward inducing the railroads and other timber consumers of this country to adopt some of the methods which have proved a success in Europe. When I visited Europe last year I took pains to investigate what is being done there, the results that had been accomplished, the various methods which had been tried, and the economy that had been obtained. The present object in giving you this lecture is, first, to give you the data which have been gathered since that report to the Society of Civil Engineers, and, secondly, to indicate to you which are the best methods to follow in preserving wood, and what is the difference between good and bad work.

The preservatives that have been used have all of them been chemical in their nature; they have acted as antiseptics in preventing the fermentation of the sap and decay of the wood. Various substances have been experimented with. . . . The French writer Paulet, in his work on the preservation of timber, gives no less than 173 different methods which had been proposed by various persons for the preservation of wood. Of all those, however, which have been experimented with in the last one hundred years, only four substances seem to have stood the test of time, viz., chloride of zinc, sulphate of copper, corrosive sublimate, and creosote. These four substances, it may be said, are practically the only ones that are now being used, and of these but two are used on a large scale—creosote and chloride of zinc.

In Europe the question of economy has long since been settled. There is no longer any question as to whether a railway is to resort to wood preservation or not. It resorts to it as a matter of course. A manager who does not avail himself of it is looked upon as neglecting his duties toward his stockholders. In the United States timber has hitherto been so very cheap that it did not pay to preserve it. It was better to let it decay and renew it with new timber, because, unless the work is well done, it is nearly useless, and it cannot be well done without incurring some increased cost. The advancing price of timber, however, has reversed that condition of affairs, so that the time has now come when in many sections of the United States it will not only pay to preserve timber against decay, but pay very handsomely, and better than many other railroad improvements. Hence the only requisite to get it adopted on a large scale is to persuade the managers that success is certain if they use the right methods and do the work thoroughly well. . . .

I will explain hereafter that the time has not yet come in this country when we can resort to metallic ties with good economy, and that until we can procure metal in this country as cheaply as in England or France the wooden tie will continue to be cheaper. In England, indeed, I found last summer that although they had experimented very largely with metallic ties, the preference was now given to wooden ties creosoted. These are obtained from the Baltic ports, and are invariably creosoted before being laid on the English railways. In France I found that every tie was prepared artificially to resist decay, and that the principal substance used was creosote. It is injected in two ways: first, in creosoting proper, that is, by giving the heated timber a bath of creosote oil, and, second, by the Blythe process, in which the vapors of creosote and steam are injected into the timber. I found the process of injecting sulphate of copper had been practically abandoned for ties and is now used only for telegraph poles.

In Germany I found that all the various processes had been gradually giving way to two, and that creosoting and burnettizing, or the use of creosote and of chloride of zinc, may be said now to be the sole systems that prevail in Germany.

In France I was able to get accurately at the economical results which had been obtained. There are on the French railroads in round numbers 94,000,000 of ties; these have been renewed for the past ten years at the rate of 4,000,000 a year, or 4·2 per cent., at a cost of $2,800,000, or 70 cents each. If they had not been prepared, it is known from the consumption which had obtained prior to ten years ago that the railroads would require 10,000,000 of ties per year to maintain their tracks, say 10·6 per cent., which, untreated, would cost $6,800,000, or 68 cents each. Hence the economy would be $4,000,000, less, however, a charge of 25 cents each for preparing the 4,000,000 treated, making thus a net gain of $3,000,000 a year by preserving these ties against decay.

I have made a calculation of what the results would be in the United States on the same basis. There are, as reported to the Department of Agriculture in 1890, 515,893,918 ties in the tracks of our railroads; the repairs annually require 60,034,647 ties, or 11·6 per cent. per year. On the French basis of 4·2 per cent. per year there would be needed instead of the 60,000,000 but 21,672,000 ties a year, so that there would be a saving, if we accomplished the same results, of 38,362,647 ties a year. These at 35 cents apiece—which I consider a very low price—obtained by assuming that some roads get their ties still cheaper, gives a sum of $13,426,926, from which, however, we must deduct the cost of preparing the 27,672,000 ties at 25 cents, making $5,418,000, and giving a net annual economy of $8,008,926. This economy it is now in the power of the American railroads to accomplish, and when they realize it, and are well assured of success, it is quite certain that they will resort to those methods which have proved successful in Europe, and that they will call upon engineers to design, build, and operate various wood preserving works.

I found that some experiments were being tried occasionally abroad with other substances, but that the field had been gone over so thoroughly that there is but little hope of finding any new substance which will be better or even as good as the old. I had heard before leaving home of the experiments of a gentleman in Rome, who had been treating some ties with arsenic, and when I was in Rome I investigated these ties. They had been laid ten years, and I found that the results were not any better than those that had been obtained with other mineral salts.

Some new experiments are being tried in this country. I may mention notably that of "vulcanizing" wood by inclosing it in iron cylinders, subjecting it to a heat from 400 to 600 degrees at a pressure of 200 lb. to the square inch, and thus, as it is claimed, partly distilling the sap which is in the wood and transforming it into various antiseptics; but my judgment is that, although the process is a good one to season the wood, it will not be found sufficient to preserve it permanently against decay, because all testimony goes to show that the germs of decay must be poisoned to prevent the fermentation of the sap and the eventual decay and destruction of the wood. . . .

Of one thing we are certain, that the conditions of decay are four in number: First, there must be moisture, and that moisture must not amount to total immersion, for if the timber is entirely submerged in water it will not decay. Second, there must be access to oxygen for fermentation to take place. Third, the temperature must be between 32 degrees and 150 degrees; below freezing point no decay takes place; above 150 degrees no fermentation takes place. Fourth, there must be present the germs of decay, and they must be active; if they are poisoned by one of the mineral salts or by creosote, the decay does not take place. It is also known, and that you will find pretty broadly set forth in the report to the American Society of Civil Engineers, that the particular process to be selected depends upon the intended subsequent exposure of the wood. If the situation be salt water or very wet, creosote is undoubtedly the proper substance to use. If it be a wooden bridge or a fence, it is probable that the best results would be obtained by the use of corrosive sublimate. If the exposure is that of a telegraph pole, it may be said that the French still use sulphate of copper; but if the exposure is to be that of a railroad tie, the experience of the Germans and in the United States seems to point to chloride of zinc or burnettizing as the proper method to use. The requirements for ties, as you know, comprise the largest consumption of wood in this country.

It has been proposed to substitute metal, and there is no doubt in my mind that the time will come within a generation when the tracks of our railroads will be largely laid with metallic ties. At present, however, it has been found that in order to have a tie strong enough to resist the wear it must be made so thick and heavy that it cannot be put down for less than $2.50 each. If the money for this be borrowed at 5 per cent., then the annual interest charged upon the first cost will amount to 12½ cents a year, which is more than the present cost of the unprepared wooden ties. Thus an oak tie will cost about 70 cents and will last about seven years. It costs, therefore, about seven cents a year a tie, as against 12½ cents interest on the metallic tie. And again, if we use a hemlock tie, which would cost unprepared 35 cents, and can be chemically prepared for 20 cents more, making 55 cents, it will then last about 12 years, making its cost 4·5 cents a year a tie, or a good deal less than either the oak tie or the interest upon the metallic tie. It is clear, therefore, in my mind that present economy in this country is going to lie in the preparation of the inferior and cheaper kinds of wood. A selection, therefore, should be made of those which are most open grained, so as to receive a large dose of the chemicals used, and which are at the same time hard, so that they shall not be cut and pounded to pieces by the foot of the rail.

You will find, if any of you ever engage in this business, that the principal difficulties you will have to contend with will be in consequence of the difference between the various kinds and qualities of wood, and that you will have to make many experiments in order to ascertain which wood is best for a particular purpose, and what is the best mode of treating it. Thus I have a record before me of a number of experiments which I have made. One set was made in July, 1886, with a lot of hemlock ties, which had been cut for two years, which were treated at the works of the Union Pacific Railway at Laramie. There were two lots of 35 ties each. They were weighed before they were charged in the cylinder, and again after they came out, the difference in their weight indicating the amount of solution which they had absorbed. That tie which increased the least in weight weighed 13 per cent. more when it came out than when it went in, that tie that increased the most gained 80 per cent. These ties ranged all the way between these limits. Here there was a lot of timber ties which had been cut at the same time from the same forest, seasoned in the same way, which showed such a difference in the character of the wood as to absorb all the way from 13 to 80 per cent. of its weight. Again, recently a similar experiment was made for the Illinois Central Railroad at Chicago with the zinc tannin process. The Illinois Central managers wanted to know whether timber growing along the line of its road would properly take the treatment, so they sent a number of ties of various kinds of wood. There were four ties of pin oak which took from 8·6 to 12·3 per cent. of their weight of solution; there were four ties of red oak which took from 13 to 21 per cent. of their weight; there were four ties of black oak which took from 15 to 21 per cent.; there were four water oak, which took from 17 to 40 per cent.; there were two beech ties which took from 9 to 10 per cent. only, while the French beech, as a rule, takes 28 per cent. There were two ties of sweet gum which took 4 to 5 per cent. only, while there was a maple tie which took 57½ per cent. of its weight; two black gum ties which took 30 and 40 per cent. respectively; two cypress absorbing 48 per cent., and one red elm which took 45 per cent., while two hickory ties which took but from 3·7 per cent. to 5·7 per cent., etc. So that you see that there is an enormous difference in the receptivity of the various woods, and that in order to do good work it is necessary to ascertain which woods will accept the treatment best.

It is also necessary to promote their receptivity so as to put them in the best condition. First, by cutting them at such time of the year when they will contain the least sap. It is for that reason that railroad ties in the North are purchased in the winter; there is then less sap and larger space in the sap cells for the reception of the chemicals which are to be injected. There is a different practice to that in the extreme South, where it is found best to cut some varieties of wood in the summer, and the reason given, therefore, is that in consequence of the drought of that time of the year there is less sap in the wood. Moreover, in order to inject the chemicals properly, the timber should be seasoned, the moisture needs to be evaporated, so that the voids in the sap cells shall be the greatest possible. The French have tried a great many experiments, and I have some before me. Thus with elm they found that when it was fresh cut it would absorb 26 per cent. of its weight of solution, but when it was well seasoned it will absorb 69 per cent. Beech, when fresh, will only absorb 21 per cent., and when seasoned it will absorb 47 per cent. of its weight. The French poplar will absorb 27 per cent. when green and 59 per cent. when seasoned. So it is evident that in order to inject the chemicals properly, trees should be cut at the right time and then should be properly seasoned.

The process which seems to be best adapted for ties in this country is that which uses chloride of zinc. It has been found by the Germans that it needs of this salt one-quarter of 1 per cent. of the weight of the wood when dry in order to effect an actual preservation. We are in the habit at the works with which I am connected of injecting twice that quantity, because of the difference found to exist between the individual trees, some absorbing more than others, and so, in order to make sure that there shall be a quarter of 1 per cent., one-half of 1 per cent. of the weight of the wood of the salt is injected. The important factor, as I have said, is to have the wood in the right condition.

It has been found by experience that the proper rate of absorption varies with the different antiseptics. For creosote ties it requires 10 lb. to the cubic foot, which amounts to 833 lb. per thousand feet of board measure, but for preservation against the teredo from 15 to 19 lb. to the cubic foot should be injected. For sulphate of copper French specifications require that the solution should be 2 per cent. strong, and that the amount of salt injected should be 0·34 of a pound per cubic foot. For chloride of zinc the solution should be 1 to 2·5 per cent. strong, and the quantity absorbed should be 0·26 lb. to the cubic foot, or 21 lb. per thousand. For corrosive sublimate there should be about 0·06 lb. per cubic foot, but that minute quantity is such that if the wood is exposed to moisture the salt will wash out more than the other salts which I have mentioned.

One difficulty is that there is no method of testing whether the work is thoroughly well done except with the use of sulphate of copper. In that case a solution of ferrocyanide of potassium, applied with a brush to the timber, indicates by the resulting discoloration the amount of copper absorbed. For the other substances the only method is chemical analysis or that of gauging at the works the quantity which is being injected by reading the indicators at the tanks; and I can best explain how that is done by describing the operation as performed with chloride of zinc at the works in Chicago. The timber treated there is hemlock, which has been cut generally from one to six months when it arrives at the works.

The works consist of two cylinders 111 ft. long and 6 ft. in diameter, in which a track is laid; on this small cars run which are loaded with the ties. Thirteen cars go in the cylinders, carrying from 350 to 400 ties. After these are inserted the doors are hermetically sealed by being pressed hard on a rubber gasket which is laid into the flange against which the door closes. Then steam is admitted to the inside of the cylinder, and it takes 30 minutes to obtain a pressure of 18 lb. to the square inch. Beyond that pressure it is not best to go, because if greater heat is applied the fiber of the wood is injured, and it has been found that not much more than 18 lb. is safe to work with. Then steam pressure is then maintained for a period of three hours, the result being to gradually warm up the wood and liquefy the sap, so as to put it in such a condition that it is most readily extracted by the next operation. That consists of blowing off the steam and then working a vacuum pump in order to reduce the pressure, when the heated air which is inside of the sap cells of the wood expands and drives out a considerable quantity of sap; this falls into the bottom of the cylinder and is pumped out. At that stage of the operation there is a

decided smell of vegetation coming from the sap, the object of all this being to open the pores of the wood and to make a place where the preservative solution may be injected. Then the valves are opened and the preserving solution is admitted, this occupying about 30 minutes.

The wood immediately drinks up a quantity of this solution, but that absorption gradually slows up and then pressure is put on, carried to 100 lb. to the square inch, and that pressure is kept up by a few strokes of the pump, as absorption proceeds, for a period of three hours. Then the chloride solution is expelled from the cylinder by pumping in air at the top, and it is thus forced back into the tanks. This occupies 30 minutes, at the end of which time a second solution of tannin is admitted, this occupying 15 minutes. Then pressure is put on the solution of tannin for the space of two hours.

The reason of this second injection is this: The first solution of chloride of zinc is mixed with a small quantity of glue, and that glue coming in contact with the second solution of tannin produces small pellicles of artificial leather, which act as diaphragms for the sap tubes, and thus prevent the zinc from being washed out. That is the theory, at any rate, and the experience in the last five or six years seems to substantiate it. The exact value of this process, however, will be better known five or six years hence than it is now. After the tannin solution is forced back, which occupies 20 minutes, the cylinder is then opened and is discharged in 20 minutes, the whole treatment occupying 12 hours; the 400 ties mentioned absorbing generally about a gallon and a half of solution to the cubic foot.

The quantity absorbed is obtained as follows:

Each cylinder is accurately gauged with 13 empty cars in it, and by reading the gauges on the solution tub at the lowest point reached, just before the surplus solution is forced back out of the cylinder and also after it is all forced back, the displacement of each load is ascertained, and thus the number of cubic feet of ties in the cylinder is known.

The solution tank being also gauged by observing the reading both before and after each run, the total cubic feet of solution absorbed by the charge is also ascertained, and the strength being known, it is easy to compute the amount of pure chloride absorbed.

We find in Chicago that there are great differences between various cargoes of ties as they arrive. These come by lake from different points on the lakes, and they are found to absorb different quantities of solution, so that whenever a new cargo comes in, its condition is ascertained by experiment and then the strength of the solution is gauged, so that at all times about the same quantity of metallic salt shall be injected. It is also found that there is a great difference in the condition of the wood between the various months. Those ties which arrive in the early part of the year require a stronger solution than those that arrive in the fall. The latter absorb the solution more readily, and the solution may then be weakened with advantage; for the weaker the solution, provided the necessary quantity of the salt be injected, the better is the result. So changes are constantly made in the strength of the solution in order to inject uniform quantities of chloride of zinc.

The desirable thing, if it could be done, would be to inject a metallic salt in solution with petroleum oil or some similar substance which would repel moisture. I investigated at the time of preparing the report to the American Society of Civil Engineers the effect of applying petroleum to wood. I found that when wood was constantly saturated by petroleum, it proved an effective preservative, but that petroleum is so volatile that if the wood was merely injected once, and no more was applied, the petroleum would evaporate; if a solution could be injected consisting of chloride of zinc or of mercury with petroleum, the mineral salt would then poison the germs of decay, while the petroleum would prevent the intrusion of moisture, and probably better results could be had than with any antiseptic except creosote, which latter is unfortunately quite expensive.

That brings me to tell you the cost of these various treatments. The cost of treatment with bichloride of mercury has been about 10 cents per tie on the Eastern Railroad of Massachusetts, but that did not provide for a sufficiently strong injection to do much good, so that the road, after working the process for five or six years, abandoned it upon finding that they did not get their money's worth. The cost of treatment with sulphate of copper would be about 24 cents per tie. It has been used to a very small extent in this country; it has not succeeded and it is not recommended. The cost of treatment by chloride of zinc is about 20 cents per tie. It can be done in different localities from 18 to 20 cents a tie, while the cost of treatment with creosote, which is the method used in France and England, if well done, would be about 60 cents a tie.

I may explain that, in this country, the normal price of creosote is eight cents a gallon, while in England it it but four cents, there being a greater demand for coal tar for roofing purposes in this country than in England, so that when the wood-preserving works want a supply they have not always obtained it at home. The supply of creosote is, moreover, growing less every year, by reason of the diminishing quantity of coal used for making gas and by the substitution therefor of water gas, which is charged with some product of naphtha as an illuminant. Therefore, while the creosote process, as an independent proposition, is the best in use, it is not the most economical. It will probably lengthen the life of a wooden tie to about 20 years at a cost of 60 cents, while at a cost of 20 cents we can lengthen the life of the same tie with chloride of zinc to 12 or 16 years. Therefore, so long as timber is so cheap in this country, it will be preferable to use the cheaper preservative.

Care should be taken after the ties are prepared to allow them to dry before they are laid. They should be piled up about two or three months, so that the moisture may be evaporated from them and leave only the preservative substance in the wood, so that it shall be in the best condition to resist a fresh intrusion of moisture.

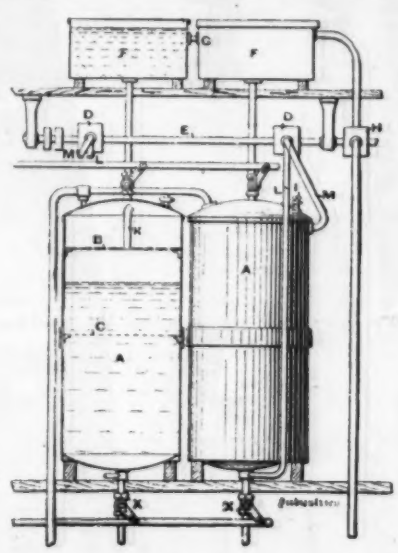
They can be marked for record in one or two ways, either by stamping an indentation at the end, or, as the Germans do, by driving in a nail with the year of its preparation in raised letters on its head, which nail is galvanized or dipped in zinc in order to prevent it from rusting. In that way, upon inspection, the year in which the tie was prepared is at once seen, and the decay and wear is accurately known.

It is very important in laying these preserved ties that the roadbed should be well drained, so that moisture shall not accumulate about the wood to promote the beginning of decay. It has been found, however, as reported in the last bulletin of the Department of Agriculture, that in endeavoring to drain the roadbed thoroughly we may encounter another danger—the tie is cut and pounded by the rail when laid on rigid rock ballast, so that it is destroyed by abrasion instead of being destroyed by decay. All these points naturally will come up and have to be studied, and I trust that such of you as may hereafter be intrusted with the doing of such work will ascertain more fully than I have done, all the various conditions of success, and will be enabled to do still better work than that which is now being carried on in this country.

MECHANICAL MATURING OF SPIRITS.

THIS is an apparatus for maturing spirits by subjecting them to the action of compressed air, the spirits, while being matured, being kept in continuous circulation in a highly subdivided state. The object is to produce the oxidation of the essential oils in the spirits, and to promote their conversion into their ethers.

The system consists of a closed cylindrical vessel or vessels, A, having a perforated partition, B, and a lower partition of wire gauze, C. This vessel is charged with the liquor to be treated, and compressed air, after being filtered through water, is admitted by a suitable pipe. The taps having been closed, the liquor is, by means of rotary pumps, D D, on the shaft, E, taken from the bottom by pipes, L, and forced into the top of the vessel by the pipes, M, and is kept in constant circulation, passing down through the perforated partition, B, in the form of a fine shower. When it falls on the gauze partition, C, it is broken up into spray, each portion of which is acted upon by the compressed air. The compressed air rises through a pipe, K, and collects in the top of the cylinder above the liquor,



so as not to interfere with the steady flow of the shower, and a slight circulation of the air is thus also effected.

At the end of the process the liquor is run into casks from the taps, X X, and the air remaining is allowed to escape by the cocks, I.

The liquor can be supplied either direct from barrels or casks, as is the case in the plant shown, or reservoirs may be used as shown at F, connected at a given level by pipes, G, and filled by a rotary pump, H. The Mechanical Spirit Maturing Apparatus Company claim that by this method they can, in twenty-four hours, effect similar results upon spirits which are otherwise only brought about by keeping them in casks for ten years.—*Industries*.

THE CORK INDUSTRY IN SPAIN.

THE cork tree is found in Spain in great abundance in the provinces of Gerona, Carcerres, and Andalusia, especially in the provinces of Huelvas, Seville, and Cadiz, and, although in less quantity, in the provinces of Ciudad Real, Malaga, Cordoba, Toledo and some others. The United States consul at Barcelona says that, according to a calculation made by the administration of forests, the extent of cork forests in Spain is about 255,000 hectares (hectare = 2·47 acres) distributed as follows: 80,000 in the province of Gerona, 45,000 in Huelvas, 32,500 in Carcerres, 28,000 in Seville, 20,000 in Cadiz, 11,500 in Ciudad Real, and 9,500 in Cordoba. In the localities exposed to the north the cork is better than in those exposed to the south, and it is seldom found in calcareous soil, preferring always that of the feldspar, this being found principally in the province of Gerona. It grows and develops in ground of very little depth, and sometimes in very stony ground. The leaves of the cork tree are oval oblong or elongated oval, frequently toothed, and the teeth jagged; length, from three to five centimeters, and width from one and a half to two. The roots are strong, and spread considerably, and are frequently to be seen on the surface of the ground. It sometimes happens that the portion of root exposed to the air produces cork, while that which is buried produces scarcely any. The most common practice is to cultivate the plant by sowing, which is frequently done, especially in ground somewhat manured, making alternate furrows with vines. Up to their twentieth or twenty-fifth year the ground is cultivated as if it were a vineyard, rooting up at that age the vines on account of producing less fruit, and also on account of the cork trees being fairly grown up, and no longer requiring the shelter of the vines. The barking of the cork may be effected when the plant has acquired sufficient strength to resist the operation, and the time chosen for this operation is in the summer. The cork of the first barking is called *corcho bornio*, *bornizo* or virgin, and is not fit for making corks. The cork taken after the first barking is called *pelas*, or secondary cork. The method employed in Spain for this operation consists in the total barking of the trunk, and not partial barking, or barking one part of the year and the remainder three, four, or five years later. In proportion as the cork is taken from the tree it is removed and piled up in heaps. Sometimes the cork is cooked in the woods, but at other times this operation is effected in the caldrons that exist in the cork factory. The slabs remain in boiling water during the space of one hour, this operation causing an increase of thickness (generally of one-fourth to one-fifth), elasticity of the cork, and dissolution of tannin and other substances. The caldrons in which the cork is boiled are of copper, and are either cylindrical or rectangular. The boiling of the cork can also be effected by steam, for which purpose it is introduced into a wooden box lined on the inside with copper or zinc, which is filled with water and steam injected therein. The steaming of cork sometimes hardens it and makes it brittle. The loss of weight produced by boiling the cork varies between twelve and forty per cent. In making corks it is necessary to take away the hard crust or *raspa*, for which purpose a tool is used with a short handle and curved blade, called *doladera*, *raspador*, or *raspeta*. A workman can scrape from two to three square meters of cork daily, and the loss in weight of the cork by scraping is from twenty to thirty per cent. Scraping machines are also used, two systems being employed, the Besson and Tousseau. The former, propelled by steam, consists principally of horizontal spindles, supplied with comb-like teeth, and turning with great velocity, at the rate of nine hundred revolutions a minute.

The Tousseau scraper attacks the cork by the means of a vertical iron shaft, carrying several knives, whose edges are also vertical, and by the rotary movement of the shaft, giving fourteen hundred turns a minute, work like a brush. This machine is simpler than the Besson, and the slabs suffer less damage when worked by inexperienced workmen. Before cutting the slabs in strips they are cooked for about half an hour, so as to facilitate the cutting, and piled up soon after in a damp place, so as to preserve the softness until ready to operate upon. The slabs are divided into three strips (*rebanadas*), the width of which is equal to the length of the corks, and in such a way that if the cork be placed in the position occupied by the slab on the tree, they would have their fibers running alike. The workmen obtain or cut the strips by means of a knife with flat surface and curved edge, called *cuchilla de rebanar*. The strips are then made into squares by means of the *cuchilla*. They then have the edges cut, and thus prepared they are ready to be made into corks. This and the preceding operation are the most difficult of the cork industry, requiring great intelligence if the slabs and strips are to be cut to the best advantage. In the manufacture of the corks, the squares made into octagons first pass into the hands of the workman, who is furnished with a knife composed of two pieces, one of them similar to an ordinary knife and the other a blade the edge of which fits into the first. Consul Schenck says that only by seeing is it possible to form an idea of the rapidity with which these men take hold of a square and from it make a cork—they hold the knife by a small iron catch to the table in front of them, and giving to the square a circular movement, the result is that the cork is made in a few seconds. The squares are usually boiled for about a quarter of an hour, they are then deposited in a cool place, and four or five days after they are sorted and kept damp until required. The amount which the workmen receive for cutting 1,000 corks varies from 0·75 to 4 pesetas, according to the kind of workmen (the peseta is equivalent to about 9½d.) Different systems of machinery are employed to make corks, and all consist, at the base, of a knife, the blade of which is placed horizontally, joined generally to a piece of wood, and to which a back and forward movement is given similar to that of a carpenter's plane. In moving, the knife turns the square cork, which being attacked by the knife takes off a strip of cork, more or less thick, according to the distance from the axle of the cork and the edge of the knife. If these are parallel, the result is the cork is cylindrical, and if it is not, it becomes conical.

The corkmaker or workman has a large basket or several of them in which he places the corks according to size or quality, but this first classification is not sufficient, and the corks are placed upon a table, the back part of which is furnished with boxes the front part of which are open to the operator. To classify the corks according to size, they also employ wooden boxes, the bottoms of which can be taken out or put in, having a kind of grating of wood somewhat resembling Venetian blinds. The boxes are suspended by ropes to the ceiling, and the workman gives it a swing backward and forward, by which the smaller corks drop out at the bottom.

With this apparatus worked by one man, 100,000 corks are classified for their size in one day. The corks are washed in a solution of oxalic acid or binoxalate of potash. As soon as washed they are placed out to dry gradually in the shade, in order to enable them to retain the silky gloss which the cork has when it is damp. For packing, 30,000 corks constitute what is called a bale. For South America and Oceania, bales consisting of 5,000 to 10,000 corks are made, and for England the sacks or bales are made to contain 100 gross or 14,400 corks for those of the larger size, and 150 gross for those of smaller dimensions. The greatest number of corks are manufactured in the province of Gerona, and the most important towns engaged in the industry are San Filieu de Guixols, Palafrugell, and Cassa de la Selva. The number of workmen engaged in the cork industry in Spain is said to be not less than 12,000.

A GAS meter is being introduced in England which it is hoped will tend to increased consumption among those who are afraid of being cheated by an ordinary meter, whose workings they do not understand. Upon the insertion of a shilling the supply is obtained, and on the exhaustion of this supply the gas is cut off. Premature cutting off of the gas can be prevented by an examination of the dial, which registers in pence.

[From The Engineer, London.]

THE WHITE STAR STEAMER TEUTONIC.*

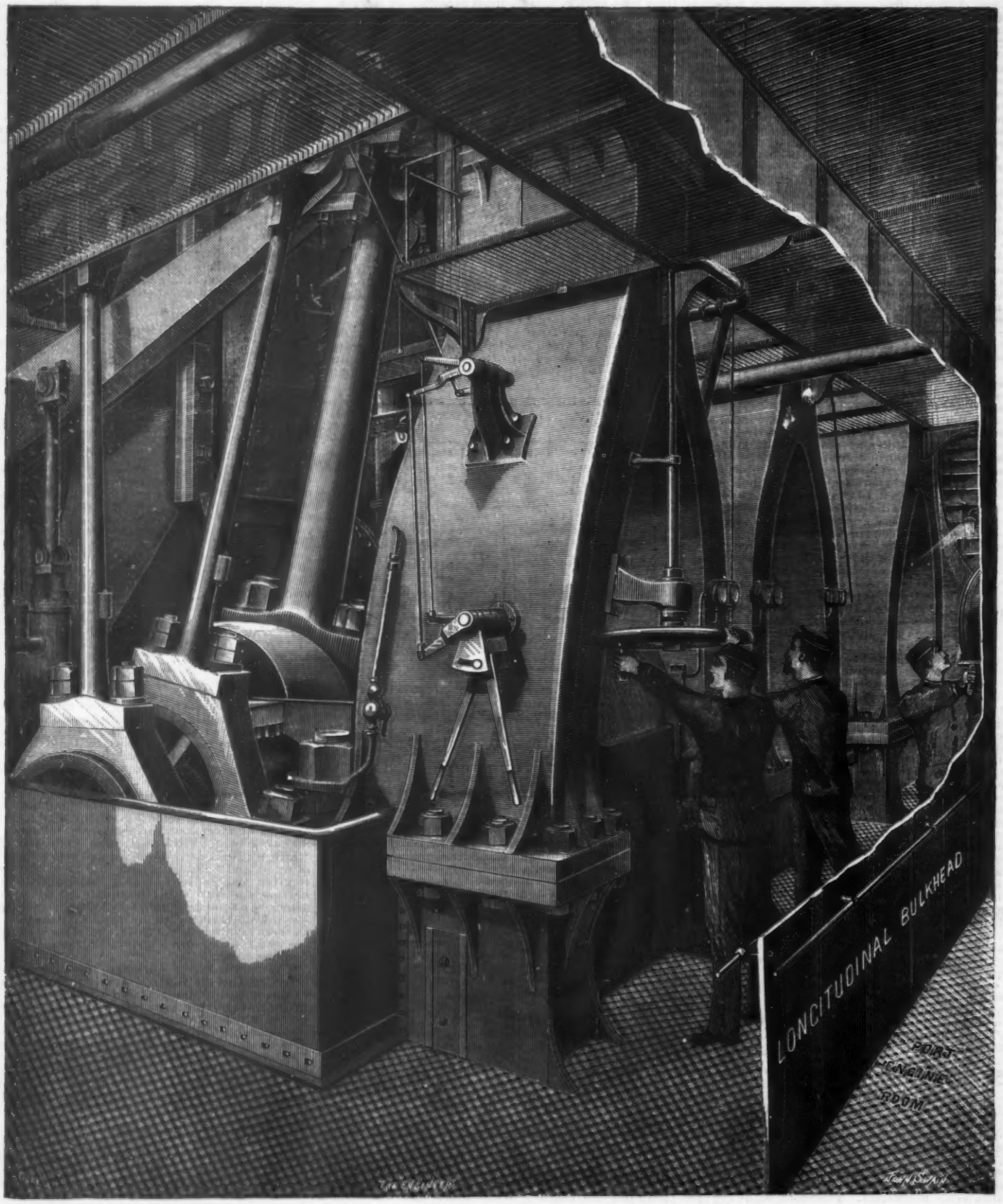
It will not be without interest if we give here a few facts and figures, which will help to convey to our readers some idea of the gigantic scale on which the processes of combustion, evaporation, and condensation, and the performance of work are carried on in the Teutonic and the Majestic. The only difficulty we have lies in selecting standards of measurement which can be readily grasped by the mind.

The engines of the Teutonic indicate about 17,000 horse power, sometimes, of course, a little less, sometimes a little more; therefore as the power is fairly equally divided among the six cylinders, each regarded as a distinct engine indicates nearly 2,833 horse power. The energy transmitted to each crank shaft is 8,500 horse power. It is far more easy to talk of 17,000 horse power than it is to realize what its development involves. The boilers of the Teutonic have to produce about 120 tons of steam per hour, with an absolute pressure of 195 lb., the safety valve load being 180 lb. on the square inch. Of course the feed pumps have to deliver 120 tons of water into the boilers against this pressure every hour. The feed water required for one hour would fill a cubical tank nearly 16½ ft. long, broad, and deep; for at 36 ft. to the ton 120 tons means 4,320 cubic feet. The energy expended in putting this great body of water into the boilers is over 57 horse power, allowing nothing for friction in pipes or losses of any kind. The feed pumps really absorb about 120 indicated horse power. The total feed water for one day of twenty-four hours amounts to 103,680 cubic feet, which would fill a cubical tank 47 ft. on the side. Such a tank would hold 6,500,000 gallons; this would be an ample daily supply for a town of 26,000 inhabitants, giving every person twenty-five gallons per day.

To convert this water into steam about 13·5 tons of coal are burned every hour, or in round numbers 320 tons a day. We do not put these figures forward as official, but they are not far from the truth. This means that on a trip to America the Teutonic burns all the coal that six trains of thirty-two wagons each can carry. The 13½ tons of coal need for their combustion not less than 270 tons of air. Assuming that this air before it enters the fans has a temperature of about 80°, it will weigh, omitting fractions, 7 lb. per 100 cubic feet. The 270 tons represent, then, 8,640,000 cubic feet, which would fill a cubical tank 206 ft. on the side. To raise this air from 80° to 180°, as is done in the heating apparatus we have described, represents about 5,800 theoretical horse power, and a large portion of this may be regarded as clear gain, being obtained for nothing. In other words, if the air were delivered cold to the furnaces instead of hot, some 20 tons of coal extra would be required per day.

The centrifugal circulating engines, as well as the electric lighting engines, were made by Messrs. Tangyes, of Birmingham. Small as the circulating engines appear to be in this great vessel, out of it they would be considered of fair size, big enough, for example, to deal with the pumping out of a pretty large graving dock. In the Teutonic the duty of these circulating engines is of the first importance. They must run constantly when the main engines are moving, they must be started before the main engines and must be kept running during all temporary stoppages, in order that the great condensers may be kept cool, and ready to deal with the immense volumes of steam which are discharged from the low pressure cylinders of the main engines.

The weight of steam to be condensed may, as we have said, be taken roughly at 120 tons per hour, a quantity which gives some idea of the important part which surface condensation has played in the progress of steam navigation. About 26,000 gallons of water are made into steam at a pressure of 180 lb. per square inch, and reconverted into water every hour. To effect this condensation about 4,000 tons of sea water are passed through the tubes of the surface condensers every hour. This duty is effected by Messrs. Tangyes' circulating pumps, and it may be interesting to state that the amount of water dealt with on the round trip between Liverpool and New York is over 1,000,000 tons —enough to fill a reservoir about a mile long, a quarter

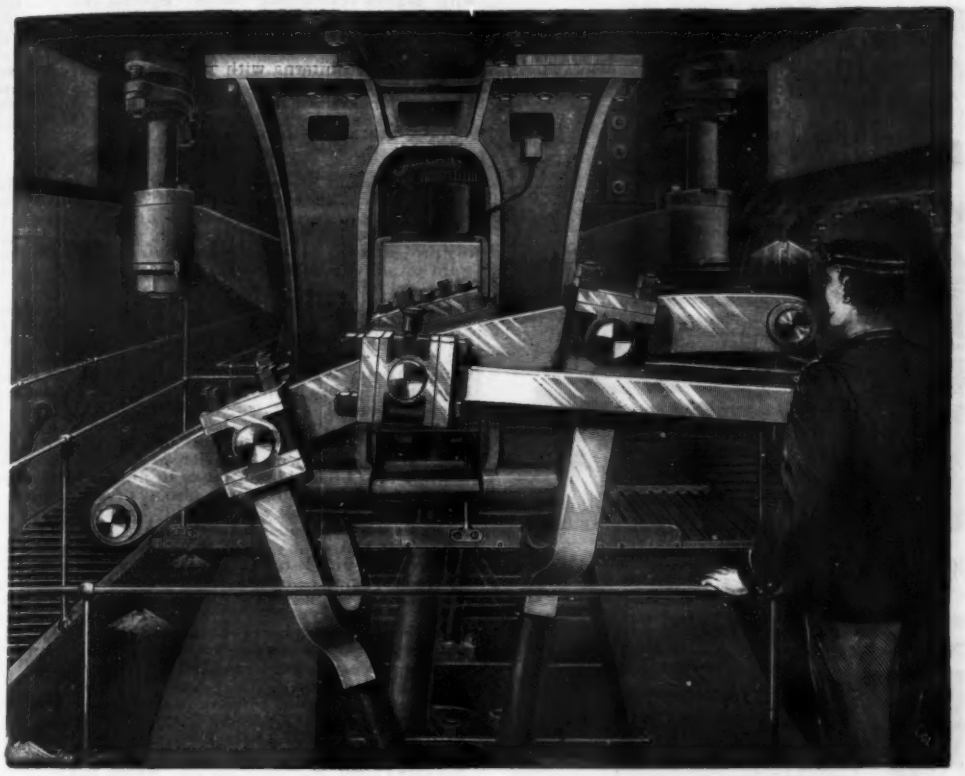


STEAMSHIP TEUTONIC—STARBOARD ENGINE ROOM, LOOKING AFT FROM STOKEHOLD DOOR.

* Continued from SUPPLEMENT, No. 788, page 12567.

of a mile wide, and 6 ft. deep; and that if the water were fresh, the daily quantity would suffice for a city of 700,000 inhabitants.

The advantage of having so much pumping power on board of large steamers is, we fear, not so much appreciated as it ought to be. Circulating pumps are



STEAMSHIP TEUTONIC—STARBOARD ENGINE ROOM—LINK MOTION, MEDIUM CYLINDER.

almost always provided with pipe connections to the bilges, or to the double bottoms; but, so far as we know, practice is not made in bilge pumping so frequently or to such an extent as to give the engineers thorough confidence in the powers of the circulating pumps for the purpose in time of disaster. In the Teutonic, however, the bilge connections to the circulating pumps are good. In each engine room there is a bilge suction pipe, commonly called the bilge injection, of the full size of the centrifugal pump pipes—20 in. diameter; there are besides two 12 in. bilge pipes running through the engine and boiler rooms and connected with the holds, so that all the auxiliary bilge pumps, and the four bilge pumps worked by the main engines, can be brought to bear on a large body of water in any of the principal holds of the ship. Cases, of course, may occur when the circulating pumps themselves are crippled, as in the unprecedented accident to the machinery of the City of Paris; still, the fact should be kept well in view that on board our largest Atlantic and Pacific steamers there is pumping power equal to discharging from the vessel over 4,000 tons of water per hour.

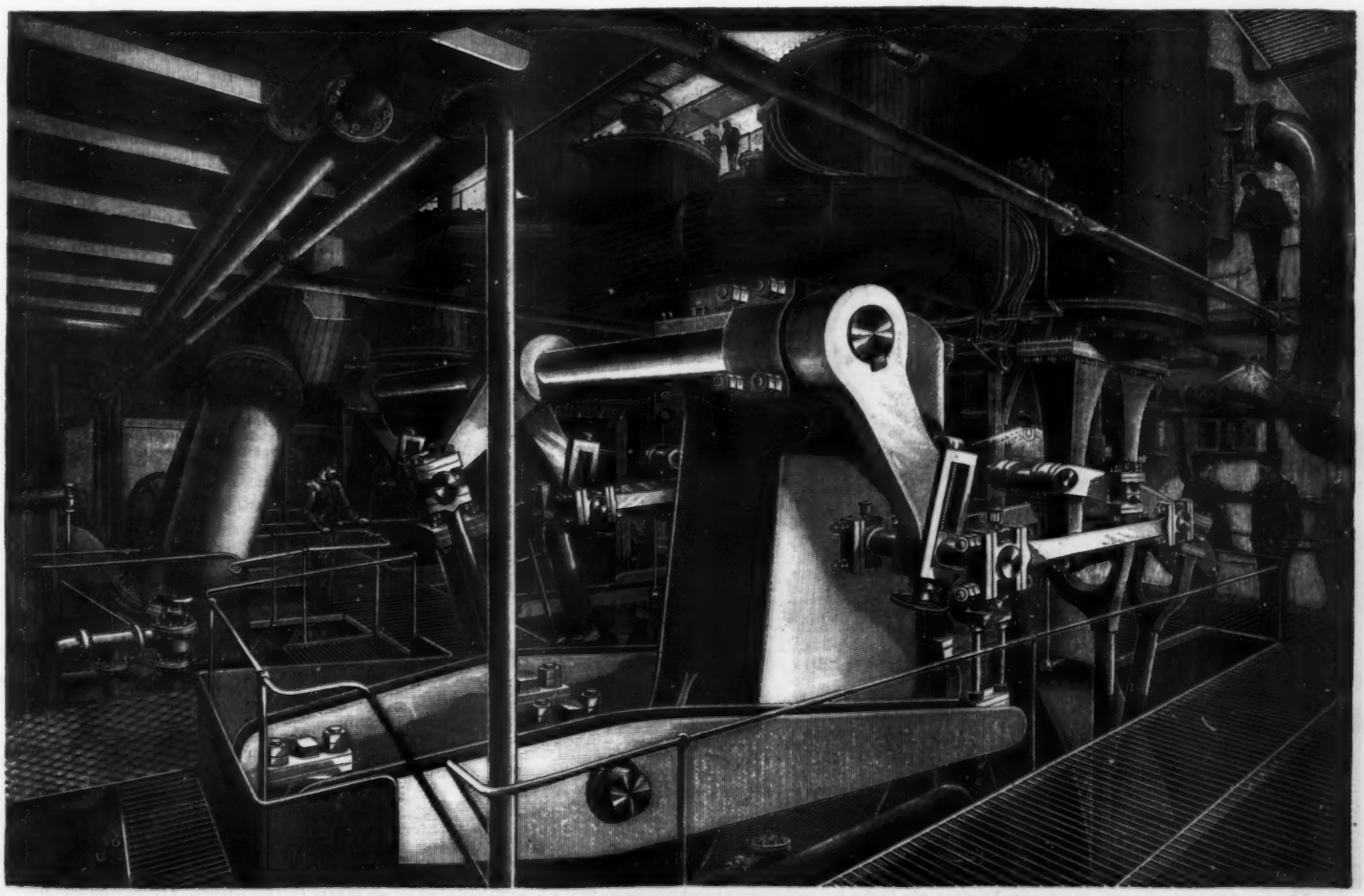
The following are the principal dimensions of these circulating pumping engines as fitted on the Teutonic: Two centrifugal pumps, each with disks or impellers 5 ft. diameter, with suction and delivery pipes 20 in. diameter. For each pump two vertical compound engines are provided, each with cylinders 8 in. and 15 in. diameter, 14 in. stroke, one engine being amply large to perform the full duty, even when lifting water 25 ft. high from the bottom of the vessel. The unusually large diameter of the disk enables the work of circulating to be done at the very moderate speed of 85 to 95 revolutions per minute when the main engines are working full speed, while the very liberal proportions and surfaces which have been adopted throughout give good security for proper working and durability. The engines are fully equipped with continuous oiling arrangements, and all the minor fittings usually found in first class work.

The enormous distances traversed by the pistons of marine engines is never realized; at all events we have never seen any statement of the facts in print. It suffices to give the speed in feet per minute; but no one stops to consider what this implies. In the Teutonic the stroke is 5 ft., and the average revolutions 78 per minute. Each piston, therefore, traverses 780 ft. per minute, or 46,800 ft. per hour, and 1,123,200 ft. per day, or in six days not less than 1,275 miles—in other words, more than one-third as many miles as the ship steams. The aggregate distance traversed by the three pistons is 7,650 miles, or about two and a half times the distance run by the ship. This is pretty well, considering that the piston rings are rubbing all the time. The length of the ring in the low pressure pistons is 347·57 in., or 28 ft. 9¼ in., so that there is a good deal of surface to take the wear, but it is not, under the circumstances, remarkable that cylinders should wear and require re-boring. The slipper guides, too, are not spared, each slipper passing over the same distance as each piston.

Referring the whole power to the low pressure cylinder of each engine, a very simple calculation suffices to show that an average effective pressure of, in round numbers, 30 lb. per square inch would develop 8,500 horse power. The work is pretty evenly divided among the three cylinders. Consequently the average total effective pressure on each piston is about 42 tons. But the initial pressures are, of course, very much in excess. Thus the initial pressure in the high pressure cylinder is about 180 lb. absolute, which, even if we allow 50 lb. absolute for the receiver back pressure, means 130 lb. per square inch on a piston area of 1,520 in., giving a total of nearly 90 tons at the beginning of each stroke, and it is for such efforts as these that all the parts have to be designed.

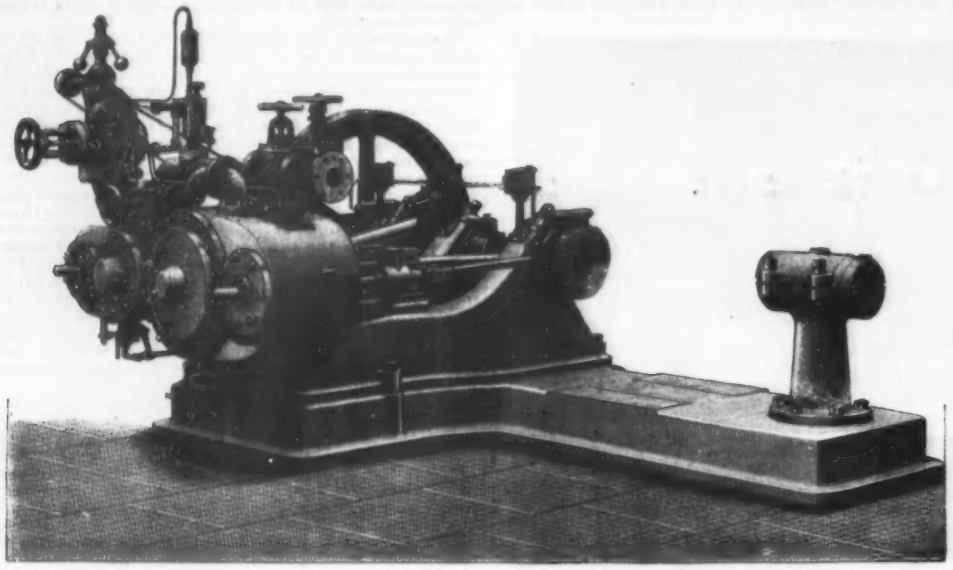
When the ship is crossing the Atlantic she will move at a speed of about 2,000 ft. per minute. Assuming that the engines and propellers have an unusually high efficiency, about 10,000 horse power out of the 17,000 indicated will reappear at the thrust bearings. A very simple calculation suffices to show that the effort on each thrust bearing will be about 36½ tons, or 73 tons for the two. There are in the two screws 216 ft. of blade area; consequently, on each square foot the water must exert a thrust of 756 lb., or 5·25 lb. per square inch. Those of our readers who are interested in propeller calculations can from this data work out the weight of water that must be propelled sternward. The pitch is 28 ft. 6 in.; this gives, at 78 revolutions per minute, an advance of 2,223 ft. in the same time; this gives about 11 per cent. slip, which is decidedly small.

The electric lighting engines, of which there are four—two in each dynamo room—have cylinders 8 in. and 16 in. diameter, 10 in. stroke, arranged to work with steam of 180 lb. pressure, and to run at 200 revolutions per minute. The rather crowded appearance of the fittings on the top of the cylinders is caused by the special steam pipe arrangements, whereby steam of 80 lb. pressure from the donkey boiler may be admitted to both high pressure and low pressure cylinders, that

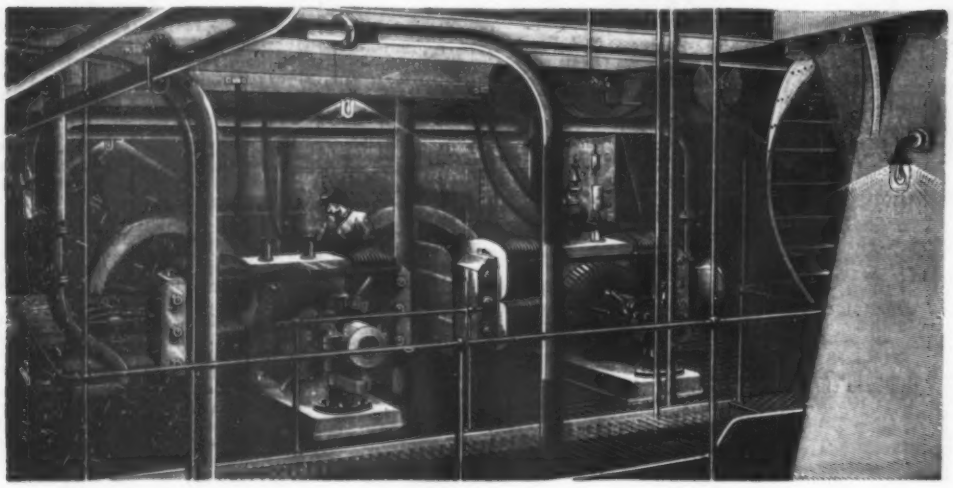


STEAMSHIP TEUTONIC—STARBOARD ENGINES, MIDDLE PLATFORM, FROM FORWARD STARBOARD CORNER.

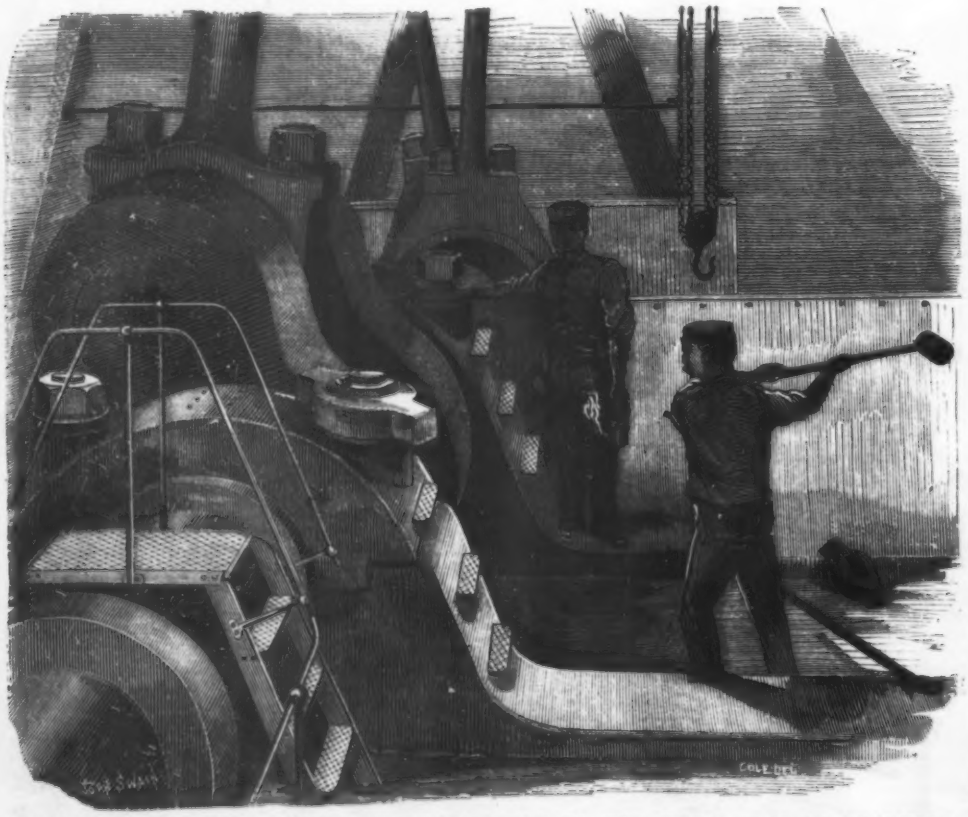
they may work as two simple engines when the main boilers are not in use. Full power can thus be obtained from the engines when the ship is in dock. The slide valves are of the piston type, the small fittings and oiling arrangements have all been tho-



STEAMSHIP TEUTONIC—ELECTRIC LIGHT ENGINES.



STEAMSHIP TEUTONIC—STARBOARD ELECTRICAL ENGINE ROOM, LOOKING AFT.



STEAMSHIP TEUTONIC—GIVING AN EXTRA TURN TO THE NUTS OF MAIN BEARINGS.

roughly worked out, and, compared with their size, these engines are probably the most substantial ever put into a ship for electric lighting purposes.

The whole of the electrical work was carried out by the Liverpool Electric Supply Company, Limited, the installation consisting of about 1,600 16-candle power lamps, and four Crompton compound-wound slow-speed dynamos, fitted to the base plates, provided with Messrs. Tangyes' engines and driven direct at 200 revolutions per minute. Two dynamos are placed in each dynamo room, and each dynamo is capable of supplying 400 lamps. The lamps are divided into 11 circuits, and the switchboards are so arranged that any circuit can be supplied at will for any one of the four dynamos. The switchboards are fitted with pilot lamps, ammeter and voltmeter and main switches for each dynamo and circuit. In the saloons and state rooms the incandescent lamps are mounted in gilt and silvered foliated holders of simple and effective design, and form part of the decoration of the ceilings. In the passages and elsewhere the lamps are mounted on substantial brackets and pendants, and are protected with globes and well glasses.

In the stoke holds strong portable lanterns are used with flexible conducting cables. Special distributing cut-outs are provided by means of which the temporary disconnection of any lamps does not affect the rest of the lighting.

Four cargo lanterns with strong copper reflectors, and each containing ten 50 candle power lamps, are arranged for use at each hatchway.

QUICK FIRING 4·7-INCH GUNS OF THE STEAMSHIP TEUTONIC.

The armament of the Teutonic, which is only to be mounted when the vessel is utilized as an armed mercantile cruiser for active service against the enemy, consists of twelve quick-firing 4·7-in. steel guns, throwing projectiles of 45 lb. weight. Four of these weapons were actually in battery upon the deck of the Teutonic when she took part in the naval pageant of 1889.

This heavy quick-firing gun was one of three, having various calibers, which were designed by the firm of Sir William Armstrong, Mitchell & Co., about two years ago. The three sizes were 4·7 in., 5·5 in., and 6 in. respectively. The smaller of the three was rapidly adopted for use in the British navy, and the more it is experimented with, the more satisfactory does it prove to be. Already it has been decided upon as forming the armament of most of our light cruisers; and, interspersed with heavier weapons, it is to be mounted for broadside purposes in auxiliary batteries on ironclads. The 6-in. gun is also at present being experimented with, and will probably be largely employed in vessels now under construction.

The gun is fired by electricity, or by percussion arrangement. In the base of the cartridge case is screwed an electric primer—in the first case—against which an insulated steel pin, carried in the axis of the breech block, presses. This pin is in communication with the electric wires which carry the current to fire the primer, only when the breech block is closed, and secured by turning the lever downward against the rear of the block. The circuit is closed and the charge fired by pulling the trigger of a pistol handle. In case of the failure of the electrical firing gear the gun is also fitted with a percussion lock; the electric primer in the base of the cartridge is replaced by a percussion primer of the same form, and the steel pin, which in the former case supplied the electrical contact, now serves as a firing needle. The percussion firing gear also has a safety appliance to prevent the charge being fired till the breech is closed and locked. So accidental discharge is rendered almost impossible.

The action on firing is as follows: The gun slides back within the rocking slide, the recoil being transmitted by the arm to the recoil press, where it is absorbed; the spring in the second cylinder is at the same time compressed. As soon as the recoil is absorbed the spring begins to act, and pushes the gun back, along the rocking slide, to its first position. The elevation and depression of the gun require very little power, as the gun and slide are accurately balanced on their trunnion bearings. A shoulder crutch and a pistol trigger are provided, and the piece can be handled by a single man.

In the earlier trials with the 4·7-in. gun a cartridge was employed with projectile and charge all in one, whole being inclosed in a solid drawn brass case, and weighing about 70 lb. It has, however, been found impracticable to adhere to the "cartridge" arrangement, and the charge and projectile have been separated. The ammunition for the 4·7-in. quick firing guns of the Trafalgar was treated in a similar manner, the 70 lb. cartridge being cumbrous and unwieldy. It is now in contemplation to use "cordite," if possible, with the large quick firers. Their usefulness at present is, of course, considerably handicapped by the volume of smoke which generates in and around the battery during rapid firing. The use of "cordite" would obviate this difficulty.

Very striking results have been obtained by practice with this gun. The following may be taken as average figures: With a charge of 12 lb. of Chilworth smokeless powder, and a 45 lb. projectile, a muzzle velocity of 2,250 ft. per second was arrived at, producing an energy of 1,580 foot tons, and effecting a penetration into wrought iron plate of 10·7 in. The rapidity of fire was twelve rounds per minute. Such a weapon would, of course, at a supreme moment, pour a veritable deluge of 45 lb. projectiles upon an enemy's vessel long before it could possibly get out of range, while a 5-in. or 6-in. ordinary steel breech loader could only get off, if splendidly served, about two shots in the course of a minute. The following table shows a comparison of the results of firing with the service 5-in. breech loader and the 4·7-in. Armstrong quick firer:

	Weight of projectile. lb.	Rate of fire. Rounds per min.	Weight of Charge lb.	Muzzle velocity per sec.	Energy foot tons.	Penetration into Plate, inches.
4·7-in. Quick F. (Elswick). .	45	12	12 s.	2,250	1,580	10·7
5-in. Breech L. (service).....	50	2	16 p.	1,750	1,060	8·2

s. smokeless powder. p. pebble powder.

Hence the application of this rapid firing gun for the armament of our mercantile cruisers cannot be too highly commended. Armed with four or six of these weapons, the Teutonic could show a clean pair of heels to the swiftest cruiser of any of the navies of Europe, after pouring in a destructive fire with such rapidity as to complete the transaction before her unexpecting enemy had time to beat to quarters. In point of fact, she would bear down upon the foe, pelt him with her iron hail, and steam away before a single ordinary broadside gun could be served against her. She might, it is true, be hulled by a chance shot at long range, but her buoyancy would not be seriously affected by an injury of this nature. The Sultan was hulled a great many times at Alexandria in 1882 upon un

armored portions of her sides, but without any detriment to the vessel. We only regret that the system of subsidizing and arming mercantile cruisers has not been more extensively developed. It is a most economical and valuable feature.

THE REFRIGERATING MACHINERY OF THE STEAMSHIP TEUTONIC.

The refrigerating machinery on board the Teutonic, as well as that on board the sister ship Majestic, is on the Linde system, and was supplied by the Linde British Refrigeration Company, limited, of Queen Victoria Street, E. C., and Lower Shadwell, E. It is used for refrigerating the insulated meat holds, and also for the passengers' provision rooms. There are two meat holds of a total net capacity of about 40,000 cubic feet, and each hold is provided with distinct refrigerating apparatus; though the arrangements are such as to permit of either refrigerator working on either hold or indeed one refrigerator on both holds. The machinery is placed below the holds between the screw tunnels, the space being very narrow, so that it was necessary to adopt a somewhat special arrangement and to use two separate machines instead of the duplex type which is now generally preferred. In the Linde system cold is produced by the evaporation under comparatively low pressure of liquid anhydrous ammonia, a liquid which possesses a boiling point at atmospheric pressure of about 37½ deg. below zero Fah. The low evaporating pressure is produced and maintained by a small pump, which draws off the vapor as quickly as it is produced, and then compresses and discharges it into a vessel, termed the condenser, in which the ammonia vapor is condensed and rendered fit for use again in the refrigerator or evaporator.

The ammonia condenser consists of a series of wrought iron coils, each in one long length of tube, so as to avoid inaccessible joints. These coils are attached to one of the end covers of the bed frame, so that when required they can be readily drawn out for examination by merely removing the nuts of the bolts or studs fixing the cover. When the machine is in operation, cold water is circulated around the coils by means of a pump so as to carry off the heat given up by the ammonia in passing from the vaporous to the liquid state. In each machine, a jet condenser with an air pump is provided for getting rid of the exhaust steam from the engine, but as a rule this is not used, as on the voyage the steam is exhausted into one of the surface condensers connected with the other machinery.

The refrigerators in which the liquid ammonia is evaporated consist of series of wrought iron tubes, wound in such a manner as to get the largest amount of surface into the smallest amount of space. There are two sets of coils, one to each machine, but one of the sets is again divided into two in order that the refrigeration of the passengers' provision rooms can be carried on independently of the meat holds. They are below the meat holds, and are well insulated with wood and charcoal, in order to prevent the passage of heat from the machine room, which, owing to its position, becomes extremely hot in warm weather. The holds and provision rooms are cooled by means of currents of cold air produced by Blackman propellers, driven by independent steam engines. These fans draw the air from the holds and pass it over the coils in which the liquid ammonia is being evaporated. In this way the air is made to supply the heat required to evaporate the ammonia, and in so doing it becomes cooled to an extent which depends upon the quantity of air circulated. In actual practice about ten degrees is a very usual reduction. The air is circulated to and from the holds by wood trunks in the usual way.

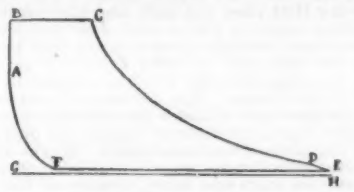
The chief advantage claimed for the Linde refrigerating system is the great economy of fuel, which is stated to be only about one-fifth of that required with the ordinary cold air machine; while the first cost is somewhat less, and the space occupied about the same. In some cases the holds are cooled by means of pipes through which brine, cooled to low temperature in the refrigerator, is circulated by means of a pump. In both cases the economy is the same, and the air is quite dry and free from snow.

THE REQUIREMENTS OF A PERFECT VALVE.*

IN deciding upon the order in which these lectures should be given, it has occurred to me that there are two ways that might be followed. First, to take the ordinary valves as they are found in everyday practice and to tell how to set them, and to point out their most vulnerable points as I have found them in my own practice; and second, to take, first, what it is a valve should do; what is required of it for the most economical use of steam, and then to show by this basis how near the different valves approach this standard; and in addition to show how the valves may be set for the best results. I have chosen the latter course, because it seemed to me that if I can give you an understanding of what is required of a perfect valve system, you may then be able to judge for yourself concerning such engines as I will not be able to touch upon. The plan that I have outlined therefore is this: First, to state the requirements of a perfect valve and what it should accomplish; then to see how the different valves do accomplish it, taking first the slide valve in its various forms, the slide valve with riding cut off, the gridiron valve, the poppet valve, the Corliss valve, and miscellaneous valves, and in addition to answer such questions as may occur to you concerning any peculiar action of the valve gear that may come under your notice.

No doubt many of you have often thought to inquire why engine builders, or perhaps some one else, did not make careful tests of all engines and settle upon a standard; in other words, that engine builders should build only one style of engine. One thing is certain, the performances of different engines cannot be alike, and if they cannot be alike, one must of necessity be better than another, and one type must be the best. Corliss, when he introduced his automatic cut off engine, marked the beginning of a new era in the history of the steam engine. The first engines he put in were not accepted by the manufacturer using them only on the basis of the saving in coal they made. Corliss agreed to take for his pay a percentage of this saving for so many years, and so successful were they that this percentage paid the value of the engines many times. But Corliss was not to have the field alone, for different styles of engines sprang up on all sides embodying the principle of automatic cut off but accomplishing it in a different manner, but none equal to the original. These are, many of them, made to-day, but with the expiration of the Corliss patents, firms all over the country began to build Corliss engines—essentially the same, and differing only in minor details. But the other builders kept on in the old path, and we have difference in styles without the merit, simply on a business basis, and because steam users do not know that there can be any difference. Every one of you, no doubt, has had men who did not know, say, "What is the difference? An engine is an engine anyway, isn't it?" Every one of you knows that an ordinary slide valve engine will not give the results a Corliss engine will, yet hundreds of slide valve engines are built every year. The engineer must take things as he finds them. But what he should do is to know what the best results are, and make the engine he has approach as near that ideal as he can.

To understand the question more clearly we will take the indicator card as a basis to work from. This instrument records simply the pressure in the cylinder at all points in the stroke. The height of the different lines above this straight atmospheric line, G, H, indicates the pressure upon the piston; the upper line, the pressure propelling the piston; the lower line, the pressure opposing it. The line, A, B, is the admission line; steam being admitted at the end of the stroke forces the pencil to a height equal to the pressure in the cylinder. The piston begins to move, and so does the drum in the indicator, and if the same pressure is



maintained in the cylinder, the indicator pencil is held at the same height and the straight line, B, C, is traced, called the steam line. At C the steam valve is closed, no more steam is admitted; that steam admitted expands as the piston moves, and as it expands its pressure decreases, the pencil falls with the decreasing pressure, and line, C, D, is traced, called the expansion line. At D the exhaust valve opens and releases the steam to clear the cylinder for the return stroke, making the release line, D, E, and the line E, F is the back-pressure line. At F the exhaust valve is closed, and the steam remaining in the cylinder is compressed by the advancing piston until the engine reaches the end of the stroke, when steam is again admitted and the process is repeated.

Now the card that I have drawn is the theoretically perfect one. Steam is admitted at a point sufficiently early to enable full boiler pressure to be realized. It is maintained at this pressure. It is cut off at a point sufficiently early to get all the work out of it possible by expansion. The exhaust is full and quick; the back pressure very light, and the compression to two-thirds initial steam pressure. This is the card that a perfect valve system would give, and the conditions stated are necessary for a perfect valve action, and if such a card is not obtained, the engineer must then inquire the reason.

A valve has four functions: To admit steam, to cut off the supply, to release the steam, and to cause some of it to be compressed. But a valve may be all right in itself but be surrounded by conditions that will not allow it to operate to the best advantage. This, too, must be considered in the matter. Let us take the first function—to admit steam. Steam should be admitted to the cylinder before the piston reaches the end of the previous stroke. The amount that the valve is opened to admit this steam is called the lead of the valve, and the object of giving a valve lead is that the steam passages may be filled with steam at steam chest pressure by the time the piston is ready to move, and sometimes to cushion the engine on the center, where there is little compression. If the opening is delayed until the engine is on the center, the steam ports must first be filled, and the piston moving away does not realize the full pressure until it has moved some distance. Then another point is that much steam is lost through condensation when the steam enters and comes in contact with the cold surfaces, that are of necessity as cold as the exhaust steam that had previously occupied the same space. This condensation lowers the steam pressure, and if the steam is not admitted sufficiently early is particularly noticeable, whereas with sufficient lead this action is completed and full pressure realized before the movement of the piston commences. There are engineers, however, who claim that a valve should not be given lead, but on the contrary the valve should be opened after the engine has passed the center. The claim is that steam being admitted, too great a strain is brought on the crank pin and bearings, and because the steam pressure cannot be utilized, no rotating force is obtained. This is working much on the same line that there is loss of power in the use of a crank, a fallacy that every engineer knows has not the slightest ground to stand upon. Some men seem to think that because of the position of the crank and connecting rod the power exerted on the piston is not fully given to the crank pin except when the crank and connecting rod, are at right angles to each other, because it does not so readily tend to produce rotation. These men forget that force and power are two different things, that power is simply the product of force and distance. The force exerted on a crank pin is not uniform because of the difference in leverage between crank and connecting rod; but as the crank pin moves faster in proportion as the force is less, there is no loss of power, then, in the use of a crank, and on this ground no reason for allowing the steam to be admitted late to the cylinder and thus losing the advantage of a high initial pressure of the steam. The best practice is to give a valve some lead. But there is no gain by using it as a cushion. Lead will appear on the indicator card by the position of the admission line, A, B. If the valve has the proper amount of lead, this line will be slightly inclined from the card. If the valve opens exactly on the center, this line will be perpendicular; and if there is negative lead, *i. e.*, the valve is late opening after the engine is over the center, the line will incline toward the card. But in view of the fact that it takes some time for the engine to pass over the center, a little lead, or negative lead, is not discernible in this manner, but in this way. If the valve has lead, the admission line will often rise in a little peak, by shooting above the steam line. Then when the valve is late the junction of the compression and admission lines, at A, will show a loop or a slight drop. This is caused by the steam condensing, when the engine is on the center, which would not occur if the valve was open, admitting live steam and also from leakage past the piston. Sometimes it is the case that ports are excessively large, but not very often, in which case some engineers advise a late opening, depending upon the width of the opening to preserve boiler pressure, but this does not always answer, owing to the great amount of initial condensation.

We will consider, then, that the first function of our valve system is to open the valve before the end of the stroke is reached. And the next point is that this opening should be wide enough and quick enough to maintain the initial pressure. When the steam is being admitted, the steam line, B C, is made, and if a constant pressure is maintained, this line will be straight. Our valve should give such a line, but there may be reasons why it should not, but instead shows a fall in pressure as the piston moves forward. The common reason for the fall in pressure is the throttling of the steam, either at the throttle or by steam pipes or ports too small, causing wire drawing. In engines with a throttling governor the card will always show a wire-drawn appearance and a fall in pressure. This is one of their defects, as will be explained later. But why should we want a high pressure maintained? Because of its economy. This can be briefly stated thus: It is one of the defects of the use of steam as a means of converting the heat in coal into useful work, that its latent heat is so great. That is, it takes so much heat to do the mere work of making the steam. We exhaust the steam, and this heat is all in it and goes to the atmosphere, and in fact the greater portion of the heat is in it at such time. A unit of heat is capable of raising the temperature of a pound of water 1°, roughly speaking. If we take a pound of water at 60°, we must add but 212—60 = 152°, or 152 units of heat to raise the water to a temperature of 212°. Now we may continue to add more heat, and it neither raises the temperature of the water nor makes itself felt until 966 of these heat units additional have been applied, when the whole pound has become steam. To get the bare steam we have expended 152 + 966 = 1118 units of heat. We go on adding heat, and we know it, for the pressure instantly rises. It is only the heat added after this point has been reached that can be used to do useful work. To obtain 10 pounds pressure we add 9 more heat units, and a cubic foot will contain 74 of these units. To obtain 100 pounds pressure, which will do ten times the work of the other, we must add but 39 more heat units, and a cubic foot contains 321 of these units. This cubic foot at 10 pounds has cost to produce it 7·46 heat units per pound, while at 100 pounds pressure it cost but 3·2 units per pound, a saving of over 50 per cent. off hand. It becomes necessary, therefore, that our valve system should allow us to use the advantages of this high pressure saving; hence it should give us as near boiler pressure as it is possible to get and maintain it there until cut off. There are conditions where losses in other directions counterbalance the gain of high pressure, these losses forming one of the great economies of the compound engine, but more of that hereafter. The point I wish to make is this, that the pressure we carry in our boiler should be admitted to the engine free and unfettered. Now what is there that will prevent it? First, a slow opening of the valve, slow despite the lead given. In such a case the opening is not wide enough to prevent wire-drawing. Or it may be the valve does not open far enough, although quick enough in opening. Or the ports may be too small. The area of a steam port should be such that the maximum flow will not exceed 100 feet per second and the exhaust port 75 feet per second. The number of cubic feet of steam per second will be the area of the piston in square feet divided by the piston speed per second, and the area of the port will be the number of cubic feet as found above divided by 100 and quotient multiplied by 144. Thus, if we have an 18-inch cylinder and a piston speed of 600 feet per minute, this would represent a consumption of steam as follows:

$$\frac{254{\cdot}47}{144} \times 10 = 17{\cdot}67 \text{ cubic feet per second, or in this}$$

proportion for any cut off. The steam port would

$$\text{be } \frac{17{\cdot}67}{100} \times 144 = 25{\cdot}447 \text{ square inches. The exhaust}$$

port would be 25·447 ÷ 0·75 = 33·92 square inches. This should be the opening of the valve for the best results, and this area can be spread out as in a slide valve or a Corliss valve, or all at one place as in a poppet valve. We will see later why it is that the area should be spread out, and we will settle that the valve must open an area based on the flow of 100 cubic feet of steam per second to get the best results. This will maintain the boiler pressure in the cylinder, provided it is in the steam chest. It may show a fall from boiler pressure in the steam chest, from insufficient size of pipes, from pipes with many elbows, each elbow being figured to cause a loss of two per cent., a great length of pipe, and loss from radiation from uncovered pipes.

As to the size of pipe, it should not be of less area than the area of port. Pipes too small are one great cause of loss in pressure, and there is a loss at every elbow if the pipes are uncovered or a poor covering used. Our supply pipes, then, must be of ample size, short as possible, with few turns and well covered, our port opening large enough and quick enough to realize and maintain as near boiler pressure as possible.

Another point may be profitably referred to here, and that is, that with ports designed alike for each end, and the valve opening alike, there will be realized less pressure on the head end than on the crank end, and this shows, too, that although steam moves rapid-

* Lecture delivered by Thomas Hawley, at the Wells Memorial Institute, Boston, in the Lowell Free Course for Engineers. *Boston Jour. Com.*

ly, still it takes time to maintain boiler pressure. The port opening is designed for a constant speed of piston, but it is a fact that on the head end the piston moves much more rapidly than on the crank end. When the piston starts from the crank end it is slow and moves more rapidly after mid stroke, while the contrary action takes place from the head end, the movement being first rapid, then slow. This is due to the angularity of the connecting rod.

The steam line should be a straight one under the best conditions, but often shows a falling off, due to wire drawing in a port opening too small, or by throttling. There is this distinction made between wire drawing and throttling, that wire drawing is less intentional and refers more particularly to the fall in pressure between the steam chest and the cylinder, while the throttling is intentional, and at the throttle valve or in the governor and is between the steam pipe and steam chest.

The next action of the valve is to cut off the supply of steam that it may do work by virtue of its expansive property. While there is a difference in pressure between the steam on one side of a piston and the atmosphere or the steam on the opposite side, work may be done by this difference. Theoretically, therefore, a valve should cut off steam at just that point that when ready to exhaust it will be at the exact pressure as that on the opposite side of the piston. We have then obtained from it all the energy it contains for use in that particular engine. This point of cut-off is somewhere between one-fifth and one-quarter stroke at 80 pounds pressure. We may cut off steam earlier than this, or later, with this loss: When cut off earlier its expansive force has departed before the end of the stroke is reached, and for a portion of the time the engine is running with more pressure resisting it than propelling it, and it would run backward but for the motion of the fly wheel. And when cut off later the end of the stroke is reached before the steam has expended all the force there is in it. We are thus throwing away power. This is the theoretical reasoning, but practically it is found that other things interfere. Chief among these is the condensation that occurs when the steam enters the cylinder, already referred to.

This is greater as the difference in the initial and terminal pressures is greater, so that it is found by practical experiment with the coal pile that if you have your engine cut off between one-quarter and one-third stroke, the best economy is obtained.

This condensation matter affects another departure from the theoretical, and that is concerning boiler pressure.

I have already shown the gain in economy by use of high pressure steam, and you may ask: Why not carry as high a pressure as we can, cut off steam very early in the stroke and expand from this high pressure down to the atmosphere? The reason is, that with the great difference in temperature between the live steam and exhaust there is caused so much condensation of incoming steam that more is lost in this way than is gained by the higher pressure and greater ratio of expansion.

The steam is condensed at the beginning of the stroke, heating the cylinder walls, and when these get hotter than the expanded steam, they give up their heat to this steam, the water therein is to a great extent evaporated and becomes steam once more, escaping into the air. There is a point, therefore, above which it is not profitable to go in a single engine, and that is between 80 and 90 pounds, depending upon conditions, and a cut off of no less than one-quarter. If the load is too light, the boiler pressure is the thing to be reduced, not the cut off, and finding the average load of the engine, I should advise engineers to fix their boiler pressure so the cut off can come at quarter stroke at the average load.

But higher pressures than 90 pounds are used in the compound engine. In this engine, as you very well know, the steam from one cylinder passes into another of larger volume and does work in that until its pressure is nearly down to that maintained by the condenser.

The compound engine is practical at low initial pressures, but at high pressures it is enabled to avail itself of the economy of high pressure and of a greater ratio of expansion, and besides these economies there is less loss from condensation. You can very readily see that if the expansion is divided between two cylinders the initial condensation will be less, because the difference in temperature is less between the incoming and exhaust steam from this cylinder. But this is added to by the condensation in the second cylinder, so that the total condensation is just the same as though it should all occur in one cylinder of a single engine. But this fact appears, that the steam condensed in the first cylinder is nearly all re-evaporated, and instead of going to the atmosphere and wasted, goes into the second cylinder and does work exactly as though it was steam from a boiler direct. Thus the steam condensed and re-evaporated is not lost, and the loss from condensation is only that of the last cylinder, the re-evaporation of which goes to and is lost in the condenser.

So with the triple expansion engine. The re-evaporated steam of the first is used in the second cylinder, and the re-evaporation of the second in the third, and we use a higher boiler pressure, a greater ratio of expansion, and only lose the re-evaporation of the low pressure cylinder. If this high boiler pressure was carried in but a simple compound, the condensation of the low pressure cylinder would be greater in proportion to the whole system, as the range of temperature in this low pressure cylinder would be greater. And so we can go on increasing boiler pressures and the number of cylinders, and with increasing economy, so long as we can build engines to stand the intense heat and pressure, and lubricants to lubricate them, and boilers to generate the steam. With some minor losses, the condensation item will be that of the low pressure cylinder, as the measure of the whole, and I would call your attention to this fact, that it must be considered with all due weight that this saving in condensation by using the re-evaporation of the high pressure and intermediate cylinders is one of the greatest economies of the compound engine.

I have diverted a little from my subject to treat of this matter, but the point I wished to make, and which led to it, was that 80 pounds is a high enough pressure for a single engine, and such engine should cut off at quarter stroke, and that when cut off the nearest approach to boiler pressure should be had. It is necessary, therefore, that the valve should be very quick in closing, so the cut off point, C, should be sharp and distinct. In no valve gear ever constructed has this been done. Those of you who see an indicator card, with cut off such as shown, may conclude, with justice, that there was a defect in the instrument, that the indicator piston bound somewhere and made the sharp corner, when it suddenly recovered itself. Some engines act quicker at this point than others, and some are naturally rapid in their action, but hindered by conditions, all of which will be explained in the lectures that follow, when these valves are considered separately.

Leaving the point of cut off for the expansion line, C, D, I will only say: Steam expanding (according to what is known as Mariotte's law) the pressure decreases inversely as the volume. That is, if the volume occupied by the steam is twice the original amount the pressure would be one half, and the steam at 80 pounds pressure from vacuum (65 gauge pressure), cut off at quarter stroke, at half stroke, occupying twice the volume, would be 40 pounds pressure from vacuum, or 25 pounds gauge pressure. In the lectures last year to you were shown how to lay out the theoretical line that the steam would cause to be made, and I will only say that it will be changed in actual practice, falling below the true line at the start, from condensation, and crossing and rising above it from the increased pressure caused by re-evaporation. It will follow pretty closely, however, the true line, and where the actual and theoretic coincide, it is presumptive evidence that everything is all right. But here the valve comes in.

It may leak, and the requirements of a perfect valve include one that does not leak, and the requirements of a perfect engine a piston that does not leak. Yet these two may combine in such a way that a good expansion line appears. A leaky valve will usually appear by an expansion line too high, especially toward the end of the stroke. The difference in pressure between the chest and cylinder immediately after cut off is so slight that little leakage results, but only enough to take the place of that condensed. But as the pressure in the cylinder is lowered, the leakage past the valve becomes more and more, because of the greater difference in pressure, and will appear by a higher terminal pressure. If the piston leaks, the leakage will be greatest at the beginning of the stroke, because of the difference in pressure, and less as expansion takes place.

Coming to the next point, the release of the steam: It should be done as quickly as possible and the opening wide enough and the exhaust pipes of ample size to produce the smallest amount of back pressure on the engine. Back pressure on an engine must be overcome by the application of an equal amount of mean effective pressure on the propelling side of the piston. Therefore it must be paid for. One pound of back pressure on an engine is as much as should be found on any engine without a heating system to look after, and then two pounds should be the limit. There is much controversy among engineers as to whether it is not better to use direct steam entirely for heating and have no back pressure on the engine than to put the extra load on an engine that the back pressure really is. I have come across many cases where this would be true, but also where a gain would come from the extra load. In one place I found an engine (a slide valve) working against 30 pounds back pressure. Such a condition of affairs you will at once see was the extreme of wastefulness, and there was no other course for me to pursue in the interest of economy than to bring the back pressure to reasonable limits and do the heating partially by this and by direct steam. Yet in another case, where an engine was decidedly underloaded, there was economy in adding to the back pressure and using it in the heating system, and thus throwing a load on the engine that would cause it to work at a more economic point. If adding back pressure for heating purposes will cause the engine to be overloaded, do not do it, and if no heating is done, then have your back pressure as little as you can. The valve then must open quickly to its full extent and stay open until ready to be closed for compression.

And when the valves are open they should be held there without further movement, for to move them means that power is required to do it. They should open quickly, remain still until ready to be closed, and then closed as rapidly as opened. The next point, the compression, depends upon the time the exhaust valve is closed, or rather the time of exhaust closure depends upon the amount of compression we want. And in most of the valve gears in use, the motion being positive and the action of the valve positive, the time of release of the steam or exhaust opening will control the amount of compression, or the time of release will be controlled by the amount of compression, whichever point you may decide upon as demanding the precedence and of the most importance. From my judgment I should recommend that the compression be the point to fix upon as of the most importance, and let the release come where it will in such engines. The various ways of bringing about a greater or less amount of compression in an engine will, of course, be considered in connection with each engine when it comes up, rather than here. Some engines it is difficult to give much compression to, which certainly must be regarded as a poor feature in their construction. Others are so arranged that the compression will change with every change in load, and here also it is difficult to change it from what the builders have given.

But in the first named case the tendency has been to give too little compression, which was erring on the wrong side, while in the latter, with changing compression, a good amount is given, sometimes to an extent to cause compression to be to a point higher than initial pressure. The point claimed by the latter builders is that when the load is light the engine can afford to cause this compression, commencing often at mid-stroke, and is really needed, whereas with a heavy load this compression should be the least possible amount that is consistent with quiet running, so as not to put this additional burden upon the engine. Such an engine, if under your charge, you would not care to alter either way, for there is never any important loss by compression, and the steam compressed will give out the amount of energy it took to compress it, but nevertheless you will, of course, understand that these builders would do with less compression at light loads if their valve gear would give it them, for many are compelled to add relief valves that will lift at the excessive compression and relieve the pressure, usually with a loud report that is not agreeable to the engineer, and sometimes placed to the discredit of the engine by those who hear it, and, not knowing the cause, ascribe it to something else.

The object of giving an engine compression is to form a cushion for the piston to carry it easily over the dead center. The piston, its rod and crosshead, must come to a full stop twice in every revolution and be started twice in each revolution from a state of rest, and when the speed is very high, the greater must the necessity for a cushion become. I have found engineers who thought there was a loss in starting and stopping, and it was one of the arguments advanced in favor of rotary engines that a great amount of power was required to start and stop the reciprocating parts of an engine. This belief was also the ground upon which was based the argument that the lighter the reciprocating parts of an engine, with no sacrifice of strength, a great saving would be made. Aside from friction being greater with the heavier parts, an item that may safely be neglected in our consideration of the subject, it will make no difference whether the parts be light or heavy within excessive limits, nor is any power lost in starting and stopping at each end of the stroke. The energy required to start the mass is stored in it and is visible in its momentum. Now to bring these parts to a state of rest, this energy must be given up to something, or the parts would go on moving forever. This momentum is given to the crank pin, as the center is approached, and does useful work there in giving greater momentum to the fly wheel.

In other words, the energy required to start the reciprocating parts and give them velocity appears again when nearing the other center, and does work in assisting to rotate the fly wheel by giving up its energy at the crank pin. Or this energy may be given up in part to the work of compressing the steam which is returned again in the expansion of this compressed steam. If the engine has no compression, the whole work of reversing the direction of motion of the reciprocating parts comes on the crank pin, and the result is a thump that is but too often heard in engine rooms.

With compression the motion is gradually and gently taken up, and if the thump is due to this cause, will prove a remedy. I was in a large mill in Fall River lately, the engine of which would tremble at the end of each stroke. The foundation was solid enough and the engine had been braced in various ways. I took some cards, and they showed very little compression, and adjusting this point, giving more compression, the engine ran as smoothly as one would wish. This trembling is seen very often in engines, and is due almost entirely to insufficient compression.

Compression should be to two-thirds initial pressure. Besides acting as a cushion, the compression heats the steam passages and prevents as much condensation of the incoming steam taking place as would otherwise occur, and fills the clearance, giving a better opportunity for a realization of higher initial pressure, especially when the valve is late in opening. You will understand from what I have said that there is no gain by compression other than comes from smooth running and filling the clearance, because it takes as much power to compress the steam as it will afterward give out, and again the condensation will be as much in amount, but of compressed steam rather than live steam. For this reason some engineers can see no advantage in compression, but they do not consider the advantage of smooth running as a gain in economy or filling the clearance space with steam of a pressure made by the energy of the reciprocating parts. I will quote to you a case because it came from one who cared only for the practical side, as you do. He had charge of a large Corliss engine, in New Jersey, that pounded.

He sent me a card, and among some other suggestions I recommended that he increase the compression as much as he could. Some time afterward I had a letter from him stating that he had increased the compression, as appeared from the card he inclosed. The thump was less apparent, but still heard a little, but what most surprised him was that his fireman came in and said: "Where have you been shutting off steam?"

He hadn't been shutting off steam, he said. But the fireman insisted it was easier to keep up steam, and he was not burning as much coal. The same load, the same conditions everywhere, except increased compression, on the engine, and a saving in fuel the result. How did it happen? he asked himself, and this is how he reasoned it out: That as the energy given up by the moving parts, near the center, could have so little rotative effect, it was better to use this energy to compress steam and save in less condensation of the initial steam and in filling the clearance with exhaust steam. It was a question of which use was the most advantageous, and he concluded his coal pile told him to go on carrying a high compression.

That is my opinion of the matter as well, so I will add as the last requirement of our perfect valve that it shall shut the exhaust port at such a point that the steam may be compressed to at least two-thirds the initial pressure.

IMPROVED TREE CUTTING MACHINERY.

WE illustrate two machines made by Messrs. Arbey & Fils, Paris, for forestry work. One machine is for sawing down trees, and the other for cutting up logs from the felled trees. In Figs. 2 and 3, which represent the former machine, the saw, A, is attached to the crosshead, B, which slides on the bars, G. The crosshead is fixed to the end of the piston rod, C, of a steam cylinder, D, and the motion of the piston in the cylinder produces the vibratory motion of the saw. The cylinder is pivoted at H to the frame, F, which carries the whole machine. At the end, K, of the frame, F, a worm, L, works a segment, M, attached to the cylinder, and thus enables the feed to be given to the saw by means of the hand wheel, N. A claw, P, attached to the frame, is inserted in the tree, and the pull of the saw draws it in more tightly. The end of the saw rests upon a piece of wood until it has got

fairly started, and when it is half way through the tree, wedges are inserted so as to take off the weight. The alternating motion of the piston is produced in an ingenious manner. The steam is admitted to the cylinder through the circular valve, E, which is controlled by the lever, Q. A twisted bar, R, of rectangular section, is capable of oscillating, in the bearings, S, about an axis parallel to its length.

The crosshead, B, is prolonged, and carries brasses, T, which compel it to turn about its axis and thus oscillate the lever, U. This lever is connected by a link with the lever, Q, which controls the valve. The action of the log sawing machine, shown in Figs. 4 and 5, is practically the same as that just described, except that the saw works in a vertical instead of a horizontal plane—the steam cylinder being supported upon trunnions. Fig. 1 gives a general view of the two machines at work in the forest. The steam is supplied by a vertical boiler on wheels. The steam is conveyed from the boiler by a strong India rubber pipe capable of standing a pressure of seven atmospheres. Four horse power is required to drive this form of saw.—*Industries.*

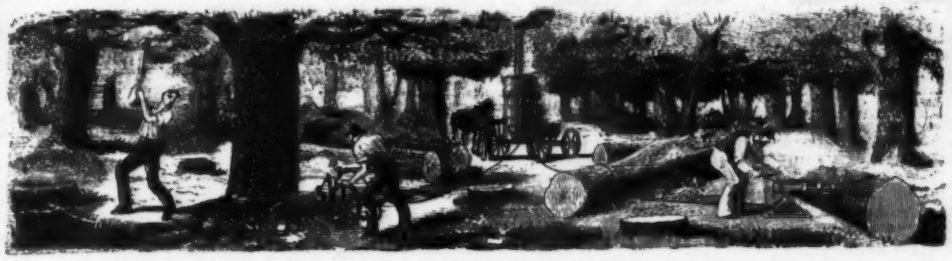


FIG. 1.—GENERAL VIEW OF MACHINES AT WORK.

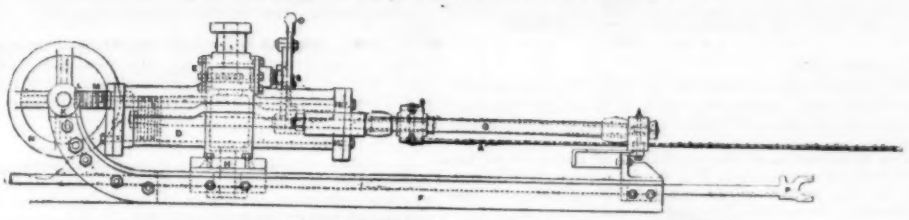


FIG. 2.—SIDE ELEVATION OF TREE FELLING MACHINE.

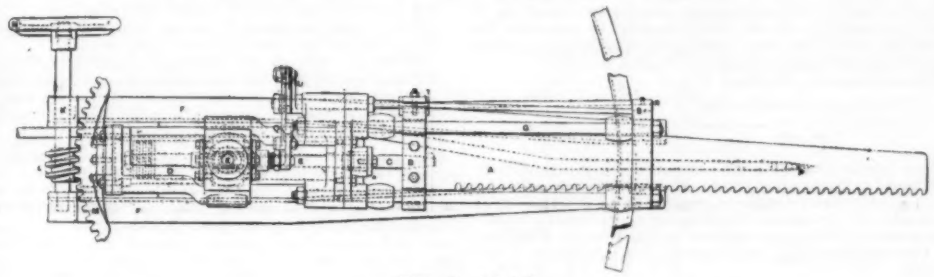


FIG. 3.—PLAN.

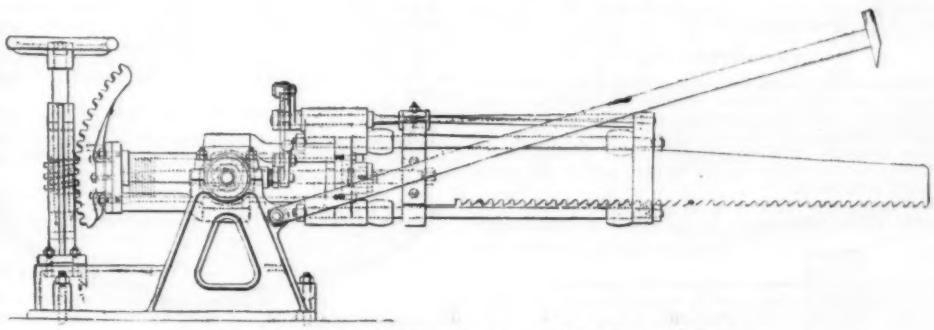


FIG. 4.—SIDE ELEVATION OF LOG CUTTING MACHINE.

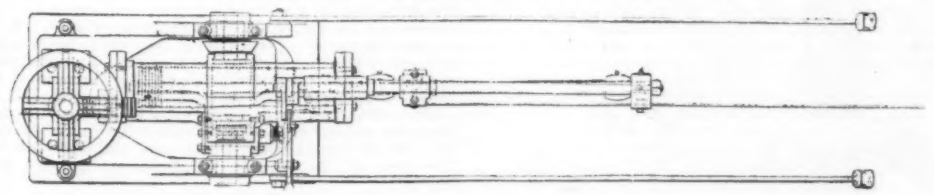


FIG. 5.—PLAN.

A NEW MODE OF WHEEL CUTTING.

A NEW PROCESS FOR GENERATING AND CUTTING THE TEETH OF SPUR WHEELS.*

By AMBROSE SWASEY, Cleveland, Ohio, U. S. A.

THE theory of the interchange system of gearing according to the solution first given by Professor Willis, in his treatise on the "Principles of Mechanism," is that "in a set of wheels of the same pitch, having a constant generating circle for the flanks and faces of the teeth, any two wheels of the set will work correctly together;" and as a rack is a gear so infinitely large that its periphery forms a straight line, it follows that, if the rack teeth are also described with the same circle as that used for the wheels, any one of the set will run correctly with the rack.

The diameter of the generating or describing circle which gives one of the best forms of teeth for a set of wheels is equal to the radius of the pitch diameter of a 15-tooth pinion, making a 7½ in. generating circle for one diametrical pitch. The flanks of a 15-tooth pinion being radial, a 12-tooth pinion, which is the smallest generally used in practice, will have the flank of one tooth nearly parallel to that of the tooth following, thus allowing the space between the teeth to be cut with the regular gear cutter.

It was thought at the time this system was first brought out that its use would be very limited, as in the case of change gears for lathes, and where it was found necessary to construct a train of gear wheels, but time has shown that it has many advantages over other equally correct systems not on the interchangeable plan, and it has been constantly growing in favor, until it is now almost universally adopted, especially among those using cut gearing.

Professor Edward Sang has also solved the same problem in another way, by taking the rack for the foundation of all curves for a set of interchange gear wheels. In the Sang theory, instead of using a constant describing circle, the rack acts as a constant generator, and the faces and flanks of all teeth throughout the whole set of wheels are described by it; therefore it is evident that if the constant generating circle which is used for a set of wheels according to the Willis theory is also used to form the teeth of a rack, this same rack can be used in accordance with the Sang theory to generate another set of wheels, and any gear of one set will work correctly with the other.

For many years, one of the foremost mechanical problems in gearing has been to reduce these well known theories to practice, and produce gear teeth having contours that correspond as nearly as possible to the theoretical curves. At first the teeth were drawn on paper or sheet metal, using arcs of circles which approximated the true curves, and then templets were made to these drawings by which the cutters were shaped; but it was found that cutters made in this way would not give as good results as desired, and afterward curves which were very much nearer the theoretical lines than arcs of circles were laid out by means of Professor Robinson's templet odontograph, and cutters made from them with much better results. Later, the curves of coarse pitch teeth were laid out, and sheet steel formers shaped to the lines as nearly as possible. These formers were then placed in a pantagraph machine, and cutters of the different pitches made from them; but it was found impossible, even with the large drawings, to make the formers sufficiently accurate.

The epicycloidal milling engine was then constructed for generating and milling the curves of one diametral pitch upon a steel plate, and, with these formers as a basis, cutters of any pitch were made. Thus step by step the process of making gearing with special cutters for each wheel, according to the Willis theory of the interchange system, has been brought to great mechanical perfection.

In the new process, which is the subject of this paper, instead of making all gears so that they will run into a rack, the rack is transformed into a cutting tool, and by it the teeth of wheels of any diameter are generated and cut at the same time.

Fig. 1 illustrates a gear generating and cutting engine, designed and constructed by the writer, for the purpose of reducing to practice the principles of this process. The cutters are shown in position as they appear in the machine when the teeth are cut partly across the face of the wheel.

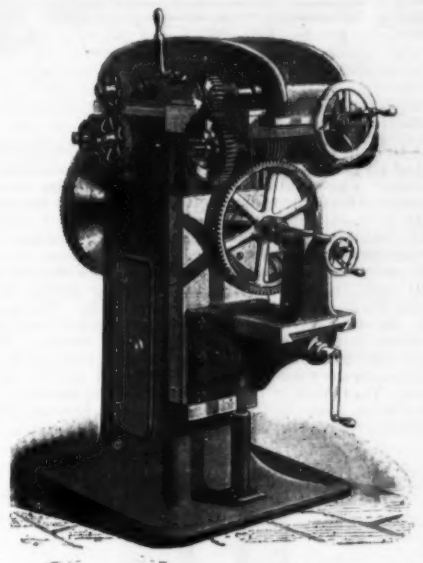


FIG. 1.—SWASEY'S GEAR GENERATING AND CUTTING ENGINE.

The cutting spindles and the main spindle which carries the wheel are connected by means of change gears, the number of teeth to be cut in the wheel determining the proportion between the two on the same principle as the change gears of an engine lathe, which gives the cutting spindle as many revolutions to one of the main spindles as there are teeth in the wheel.

The cutting tool is composed of a series of cutters rigidly connected, which revolve and at the same time move longitudinally or endwise at right angles to the axis of the wheel to be cut; and at the same speed, it is continually revolving at the pitch line, the motions being the same as in the case of a rack engaging with a revolving gear.

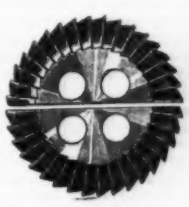


FIG. 2.

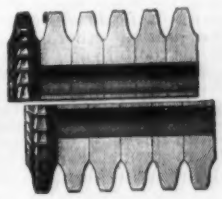


FIG. 3.

As it would be impracticable to continue moving the whole series of cutters endwise, they are bisected, and these segments are connected in series forming two sections, which revolve upon a common axis, and each section is given an independent endwise motion by means of a cam. When one section is engaged in cutting, it is carried endwise in the same direction and at the same velocity that the pitch line of the wheel is revolving, until disengaged from it, when the cutters, while continuing to revolve, are carried back by the cam to their original position, ready for the next tooth. By means of both sections, as they continually revolve and alternately slide forward while cutting, and back when disengaged, there is a continuous cutting and generating process of the teeth in the revolving wheel. The head carrying the cutters is automatically fed across the face of the wheel, and when the cutters have proceeded once across the gear is completed.

Fig. 2 is a side elevation of a bisected cutter, and Fig. 3 shows a series of six cutters, the end one being in elevation and the others in cross section—these having cutting portions, which in cross section represent the teeth of a rack, with the addition to the diameter of a given proportion of the pitch by which the clearance and fillets at the bottom of the teeth are made. If their cutting portions are formed of cycloids, then the whole set of gear wheels cut with them will be of

* Paper read before the American Society of Mechanical Engineers at the Richmond meeting.—*Engineering.*

the epicycloidal or double curve system. If they are formed simply of straight sides, then a set of involute or single curve gears will be generated and cut, or their cutting portions may be composed of both straight lines and cycloids and produce Professor MacCord's recent system of gearing, which has composite teeth with the contours partly involute and partly epicycloidal.

All the cutters in a series are made exactly alike and interchangeable, the thickness of each or the distance from the center of one to the center of that adjoining being equal to the pitch of the gear to be cut. As indicated in Fig. 2, the two segments of a cutter are first made whole, with four holes an equal distance from the center, through which the rods pass that fasten them together. After the cutters are nearly completed, they are bisected with a narrow tool, leaving two holes in each segment.

Fig. 4 is a cross section of the head, showing the mechanism for revolving and reciprocating the cutters. The rods which extend through the cutters serve not

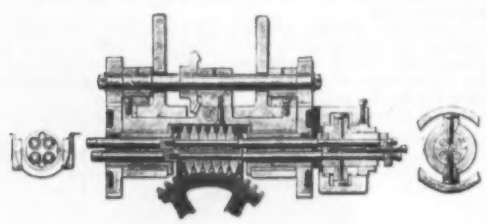


FIG. 4.

only to hold them firmly together, but to revolve them, and at the same time act as slides for the reciprocating motion. The spindles on either side of the cutters, through which the rods extend, are revolved independently and at the same speed by means of a parallel shaft, having a pinion at each end, which engages with a large gear on each spindle. By this means the four rods carrying the two cutter sections are revolved from each end, thus avoiding the torsional strain which would result if driven from one end only. The pair of rods for each section, after passing through one of the spindles, terminate in semi-cylindrical blocks. From these blocks studs extend, on which are journaled rolls, which engage with a cam which is held rigidly to the head. This cam is shown in Fig. 5, the working portions being made in the form of a screw thread, which, if extended all the way around, would have a lead

FIG. 5.

equal to the thickness or pitch of the cutter. As each section of the cutters engages with the wheel but three-fourths of a revolution, the thread portion of the cam which carries the cutters forward extends only three-fourths of its circumference, leaving the other one-fourth for the reverse curves of the cam to bring the cutters back to their starting point. Provision is made for adjusting one section of cutters so as exactly to coincide with the other, making the spaces and teeth of the wheel equal, or, as is often necessary, the space can be made wider than the teeth by setting one section past the other. The variation in the spacing from one tooth to another is reduced to a minimum, as the series of cutters act upon both sides of a number of teeth at the same time, and serve to average and eliminate any local inaccuracies in the division of the index and driving gears; also to obviate any tendency to crowd the wheel from one side to the other.

The forward motion of the cutters and the revolving of the wheel at the pitch line being exactly the same, the process of generating and cutting the teeth goes on continuously and uniformly around its entire periphery, so that one part is not heated more than another, but all the teeth are cut under exactly the same conditions, and when the revolving cutters have once passed across the face, all the teeth in the gear are completed and given the correct form for each diameter of wheel; and as by the Willis theory all gears are cut to run into a rack, so by this process the Sang theory is put into practice, and a rack is made to cut correctly all gears.

[Continued from SUPPLEMENT, No. 788, page 12589.]

THE POWER OF WATER, OR HYDRAULICS SIMPLIFIED.

By G. D. HISCOX.

FLOW FROM SUB SURFACE ORIFICES.

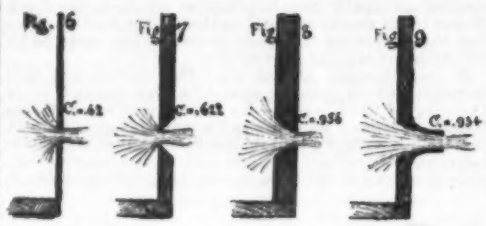
THE velocity of a fluid issuing from a hole or aperture of the best form in a reservoir is theoretically the same as it would be if it fell from the height of the surface of the water in the reservoir to the center of the hole or aperture. It varies as the square root of the height and is found to be equal to the square root of the sum of twice gravity (64·32) and the height; the formula of which is:

$$\sqrt{2g \times h} \text{ or } 8{\cdot}02 \times \sqrt{\text{height}}$$

Thus for a fall of 1 foot the velocity is $\sqrt{64{\cdot}32 \times 1} = 8{\cdot}02$ feet per second, and for a fall of 16 feet it is $\sqrt{64{\cdot}32 \times 16} = 32{\cdot}08$ feet per second.

Practically, friction and the forms of orifices of issue make a reduction from the theoretical values, except in some peculiar forms in which the velocity exceeds the theoretical value.

The coefficient of discharge may be briefly stated for all ordinary tests for volume of discharge to be from an orifice in a thin plate, or a hole in a plank with a bevel on the outside brought to a sharp edge upon the inner side; or a nozzle not longer than three times the diameter of the smallest part, as shown in Figs. 6, 7, 8



and 9, in which the coefficients are marked for each form of orifice.

The measure of any orifice, opening or nozzle should always be its smallest diameter.

For the quantity delivered from these forms of orifice, the rule for which is, the velocity in feet per second multiplied by the area in square feet or decimals of a foot, gives the volume in cubic feet per second.

For obtaining the area, multiply the square of the diameter in inches by 0·7854 and divide the product by 144; which will give the square feet, or decimals of a square foot as a multiplier in the above rule for cubic feet per second.

As an example say for a 3 inch orifice or nozzle the area will be

$$3'' \times 3'' = 9'' \times 0{\cdot}7854 = \frac{7''{\cdot}0686}{144''} = 0{\cdot}04909$$

of a square foot.

The velocity for a spouting jet will be theoretically for 16 feet head, equal to $\sqrt{64{\cdot}32 \times 16} = 32{\cdot}08$ feet per second, and $32{\cdot}08 \times 0{\cdot}04909 = 1{\cdot}5748$ cubic feet per second.

The application of the coefficient of delivery for the best form of orifice as in Fig. 8 will reduce the theoretical to the actual value, and $1{\cdot}5748 \times 0{\cdot}956 = 1{\cdot}5055$ cubic feet, the actual flow per second.

In order to turn the value of this flow into horse power, multiply the volume by 60" (seconds in a minute) and by 62·5 (pounds in a cubic foot) and by 16 (feet in height); divide the cumulative product by 33,000 (lb. lifted one foot high per minute), the quotient equals the gross horse power.

The expression will then be:

$$\frac{1{\cdot}5055 \times 60 \times 62{\cdot}5 \times 16}{33{,}000} = 2{\cdot}737 \text{ horse power}$$

The realization of work from this gross power requires a further reduction for the inefficiency of water wheels, motors or turbines, the value of which varies from 65 to 85 per cent. of the gross power of the spouting stream, taking the highest coefficient for a turbine or Pelton wheel and multiplying by the above gross power

$$0{\cdot}85 \times 2{\cdot}737 = 2{\cdot}326$$

the actual horse power available for work for the best form of water wheels.

THE MINER'S INCH.

A miner's inch is the measure of water established in the early days of hydraulic mining, and may be defined to be the quantity of water that will flow from a square orifice in the side of a flume, one inch in diameter, through a two inch plank, the center of the orifice being 6½ inches below the surface of the water or a 6½ inch head.

The ratio or coefficient of actual to theoretical discharge varies somewhat in the trials of experiment-

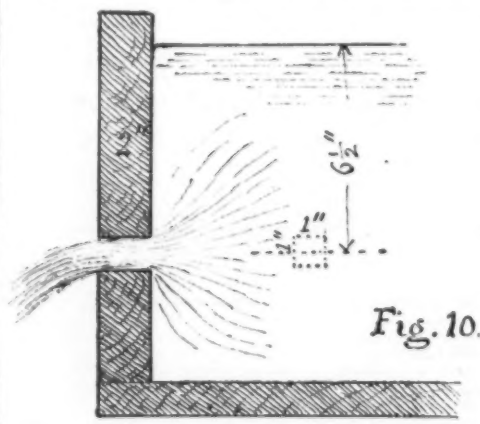


Fig. 10.

ers, from 0·623 to 0·616, so that the actual flow may be from the rule for one miner's inch. (Fig. 10.)

RULE.

Area in decimals of a square foot × coefficient × sq. root of twice gravity × square root of height in feet, or

$$A \times C \times \sqrt{2g \times h}$$

or

$$0{\cdot}006944 \times 0{\cdot}623 \times 8{\cdot}02 \times \sqrt{\frac{6{\cdot}5}{12}} = 0{\cdot}0255 \text{ cubic foot per}$$

second, and $0{\cdot}0255 \times 60'' = 1{\cdot}53$ cubic feet per minute = a miner's inch of water.

The actual value or flow seems to vary considerably at various elevations, and values are quoted at from 1·25 to 1·75 cubic feet per minute for actual discharge, the less in quantity for the greater height.

From experiments with exact measurements of orifice, height, time and flow at moderate elevations in California, the mean flow of a miner's inch was found to be 1·5744 cubic feet per minute, with an ascertained coefficient of 0·616.

The variation of water level in flumes makes a uniform flow somewhat difficult of control, and a resort to gates regulated by floats is made where uniform flow is required.

The available horse power, from one or any number of miner's inches, may be readily computed by multiplying the number of miner's inches by their volume per minute (1·5744 × number of in.), and by the weight of a cubic foot of water (62·5), and by the fall in feet that can be obtained, dividing the last product by 33,000, which gives the value of the horse power of the water. From this a deduction of 20 per cent. should be made for the loss by transmission of the power through the motor, which is also a variable and is the mean of various kinds ranging in efficiency from 75 to 85 per cent.

The most approved forms of turbines and impact wheels are found to yield from 80 to 86 per cent. of the primary power of the water.

Thus as an example: For 100 miner's inches and a fall of 100 feet, the figures of the equation become

$$100 \times 1{\cdot}5744 \times 62{\cdot}5 \times 100 = \frac{984{,}008}{33{,}000} = 29{\cdot}8 \text{ h. p.}$$

and 29·8 less 20 per cent. = 23·84 available horse power.

THE FLOW OF WATER IN OPEN STREAMS AND DITCHES.

The flow of water in streams, canals and ditches and their hydraulic grades or slope is a somewhat complex problem, arising from the friction of the bottom and sides varying with the kind of material with which they are lined, as well as the varying velocity due to varying areas; the friction being inversely as their areas.

For irrigation ditches, where the lining is of fine material, as sand, loam or clay, the flow will have the least friction; but curves and angular bends have an influence in retarding the flow due to a given slope or hydraulic grade.

THE SCOURING ACTION OF WATER.

As undue velocity has an abrading effect upon the material of the bottom and sides of channels, various experiments have given us a gauge for guidance in laying out the hydraulic slope of canals and ditches. Its effect has been found to be for a mean velocity of—

0·4 of a foot per second, moves fine clay.
0·5 of a foot per second, moves loam and fine sand.
0·8 of a foot per second, moves fine gravel.
1·0 feet per second, moves coarse gravel size of beans.
3·5 feet per second, moves shingle 1 inch in diameter.
4·5 feet per second, moves stones 1½ in. diameter.
6·0 feet per second, moves stones 3 to 6 in. diameter.
10·0 feet per second, moves bowlders and rocks.

To an observation of surface velocity at center of stream deduct 10 per cent. for mean velocity.

The velocity close to the bottom or next to the wet perimeter is very much less than at the surface at center of stream, and varies with the condition of roughness and form of the bottom; 20 to 30 per cent. difference has been observed, but the conditions of form and roughness are so uncertain, that the above rule will be found practical for all ordinary purposes.

A few definitions may here make plain the terms of computation for velocity and slope of streams, canals and ditches, under various conditions.

The area of a stream, canal or ditch is the width multiplied by the mean depth as described in chapter 1, Fig. 1.

THE WET PERIMETER.

The wet perimeter is the measure of a stream, canal or ditch following the irregularities of the bottom and sides, as shown in Fig. 11.

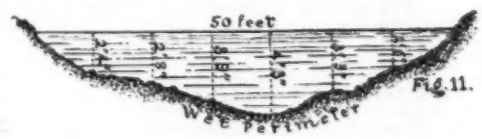


Fig. 11.

As the wet perimeter is an important factor in the computation of the slope of a stream, canal or ditch, the means for approximately obtaining it from the set of measurements for area is desirable for natural streams, while for canals and ditches of known dimensions, the wet perimeter can be measured on a sectional drawing.

For natural streams, to the sum of the outside measures for mean depth add the difference between these and the next measure successively, and also one-half the sum of the outside measures as follows, from Fig. 11.

Make this sum and the width of the stream the two legs of a triangle, Fig. 12, and to the square of the

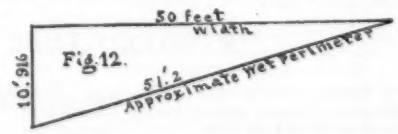


Fig. 12.

width add the square of the sum of the depths, and from this sum take the square root for the angular wet perimeter:

Sum of outside measures.....	2′ 4″ + 2′ 6″ =	4′ 10″
Differences.....	4′—13″—6″—12″—9″ =	3′ 8″
One-half the sum of outside measures		2′ 5″
		10′ 11″
Or decimally.....		10·916

Then—

$$50^2 = 2500$$
$$10{\cdot}916^2 = 119{\cdot}14$$
$$\sqrt{2619{\cdot}14} = 51{\cdot}2$$

The angular wet perimeter being found to be 51″·2, add, for roughness and inequalities of the bottom be-

tween the measured divisions, 5 per cent. to the angular amount, making a wet perimeter of 51·2 + 5 per cent. = 53·76, a very near approximation to the measured wet perimeter of such a stream.

For canals and ditches with flat bottoms and straight sloping sides, the operation becomes an easy one, as, for example, the following form, Fig. 13:

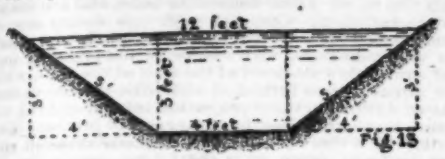


Fig. 13

Here the slope of the sides make equal and similar triangles, and as both triangles make a rectangle 4' by 3', the solution for area becomes a very simple one, viz., 4' + 4' × 3' = 24 square feet.

The wet perimeter is then found by obtaining the length of the slope; which is equal to the square root of the sum of the squares of the horizontal and vertical sides of the triangle, viz.:

$4^2 + 3^2 = 25$, and the square root of $\sqrt{25} = 5$, the slope. Then 5' + 5' + 4' = 14 feet, for the wet perimeter.

THE HYDRAULIC RADIUS.

The hydraulic radius, another factor in the problem of the slope or hydraulic gradient and its consequent current, is the area of the transverse section of a stream, canal or ditch, in square feet, divided by the wet perimeter, in lineal feet.

For example, as in the first case, Fig. 11, the sum of the measures for depth amount to 18" or 1·75 feet, which, divided by 6, the number of measures, = 3·225 × 50 feet = 161·25 square feet, the area of the stream,

and $\frac{161{\cdot}25}{53{\cdot}76} = 2{\cdot}99$ the hydraulic radius sought.

For the second case, Fig. 13:

$$\frac{24}{14} = 1{\cdot}714$$

the hydraulic radius sought.

The trapezoidal form of canals and ditches, as above described and proportioned, approximates very nearly to the best form for irrigation ditches in gravel, sand and loam, as the slopes of the sides will hold with mean velocities below 2 feet per second.

THE SLOPE OR HYDRAULIC GRADIENT.

For the velocity of flow in rivers having a uniform area, we have the formulas for velocity from a given slope, and, by inversion, the slope for a given velocity:

1st. 1·2 $\sqrt{\text{hydraulic radius} \times \text{slope in feet per mile}}$ = velocity in feet per second.

Thus, for example, as for Fig. 11, with a hydraulic radius of 2·99 and an assumed slope of 2 feet per mile:

$1{\cdot}2\sqrt{2{\cdot}99 \times 2} = \sqrt{5{\cdot}98} \times 1{\cdot}2 = 2{\cdot}93$ feet velocity per second.

For the velocity of flow in canals and ditches of uniform area and smooth bottom, we have the formula:

2d. $\sqrt{\text{hydraulic radius} \times 2 \times \text{slope in feet per mile}}$ = velocity in feet per second.

Assuming the hydraulic radius of the canal or ditch as in Fig. 13, with a slope or hydraulic grade of 1 ft. per mile,

Then $\sqrt{1{\cdot}714 \times 2 \times 1} = 1{\cdot}85$ ft. velocity per second.

The widening of such a ditch to 24 ft., with the sides of the same slope and depth, makes a marked increase in the velocity of the current with the same hydraulic grade, or will allow of a less grade for the same current, as an example will show.

Width at top 24 ft., bottom 16 ft., sides as in Fig. 1i. Then the area will be 20 × 3 = 60 sq. ft., and the wet perimeter will be 5 + 5 + 16 = 26 ft., and $\frac{60}{26} = 2{\cdot}307$, the hydraulic radius.

Then $\sqrt{2{\cdot}307 \times 2 \times 1} = \sqrt{4{\cdot}614} = 2{\cdot}15$ ft. per second for velocity of the current. As this is too swift a current for canals or ditches with a lining of sand or loam, some other grade may be adopted, say ¾ ft. to a mile, which with the above formula will give a velocity of 1·86 ft. per second, or an inversion of the formula may be used to adapt the grade to a required current, as shown further on.

For ascertaining the required slope or hydraulic grade for any given velocity of current per second with an assigned hydraulic radius for a canal or ditch, the formulas Nos. 1 and 2 may be inverted as follows:

3d. $\frac{\text{velocity in ft. per second}^2}{\text{Hydraulic radius} \times 2} = \text{gradient in ft. per mile.}$

Taking the second example, Fig. 11, the computation

becomes $1{\cdot}85^2 = \frac{3{\cdot}428}{1{\cdot}714 \times 2} = 1$ ft. per mile slope or hydraulic gradient.

With these data for an irrigation ditch twice the width with a required velocity of 2 ft. per second; the equation

3d $\frac{2^2}{2{\cdot}307 \times 2} = 0{\cdot}866$ ft. per mile for the slope or hydraulic gradient.

The ditch, as in Fig. 11, with a current velocity of 1·85 ft. per second and a hydraulic grade of 1 ft. per mile, will deliver 24□' × 1·85 = 44·4 cubic ft. of water per second, or over 3,800,000 cu. ft. per day of 24 hours.

The slope of the old Croton aqueduct is 1·1 ft. per mile. The new aqueduct has a less slope, due to its larger area, being 8⅛ in. to a mile.

These low grade slopes were made to meet the requirement of a nearly perfect wet perimeter.

In practice, the ditches for irrigation purposes, where the length is less than five miles, should be made level, with depth enough to balance the hydraulic grade, so that waste weirs will not be required, that the water catch may all be saved during a time of drought.

Reservoirs wherever practicable along the line of main ditches are of great importance, in arid districts, especially where the source of supply is a flood stream that may become dry during a drought. At such times, a single irrigation from a stored supply at the opportune time will often save a crop.

In regard to the quantity of water required to save a crop on a given size farm, no definite figure can be given under the varied conditions of climate and rainfall, yet it has been estimated that, for a larger part of the arid lands of the United States, a depth of three inches on the whole acreage during the dry season will save a crop.

A depth of 6 in. will be sufficient in the more arid districts of Arizona and New Mexico.

Taking for example a farm with 100 acres under special cultivation, the quantity required for a seasonal depth of 3 inches will be about 1,089,000 cub. ft., and for 6 in. in depth 2,178,000 cub. ft.

These figures look large, but a ditch of 5 sq. ft. water area, or say 4½ ft. wide by 1⅛ ft. in depth, at a velocity of 1 ft. per second, will meet the supply of 3 in. in depth over 100 acres in 14 days, and of 6 in. in depth in one month.

This will be more than enough for a continuous drought of two months.

The possibilities of storage by artificial ponds or lakes is of the utmost importance where the source of supply is limited; and although not always feasible by dams in the streams, a series of reservoirs along the line of ditch may often be made available for the storage of one or two million cubic feet of water, and in this way save the cost of large ditches and make available the smallest streams by the cumulative process through the rainy season.

Where pumping is required we refer the reader to descriptive articles on pumping devices for irrigation in SCIENTIFIC AMERICAN SUPPLEMENT, Nos. 624 and 625; illustrated descriptions of hydraulic rams for purposes of irrigation in Nos. 111 and 155; and of Pearsall's hydraulic pumping engine in No. 544.

As the Pearsall engine has been modified for larger and important work since the issue of No. 544, we give an illustration of its latest form, in which 75 per cent. of the total water power used is claimed to be utilized for irrigation purposes. One of these engines now running at Barneston, Pa., with 17 feet fall, lifts 180,000 gallons per day to a height of 100 feet. This is a capacity equal to covering 100 acres of land ⅛ inch deep every week. With 8 feet fall and 50 feet lift, and for other proportions of fall and lift, this form of water engine retains its full discharge as above stated.

For gardens and small farms, where only partial irrigation is needed, say up to 15,000 gallons per day, enough for a ten to twenty acre lot, Rife's automatic hydraulic engine has some of the latest improvements for economy with small fall.

(To be continued.)

PEARSALLS HYDRAULIC ENGINE.

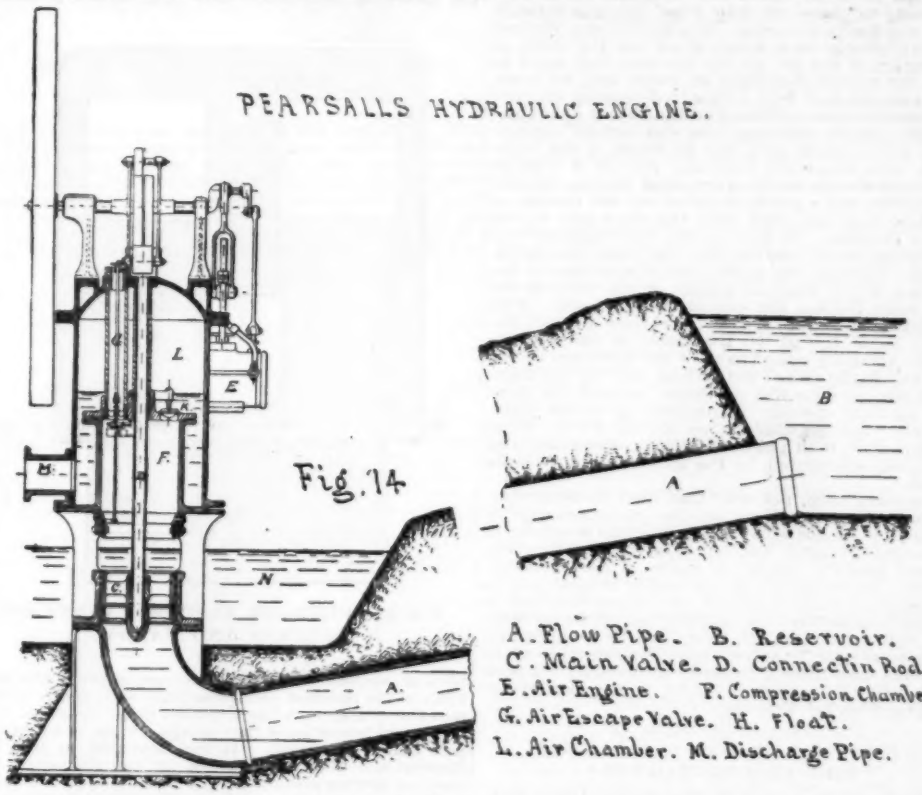


Fig. 14

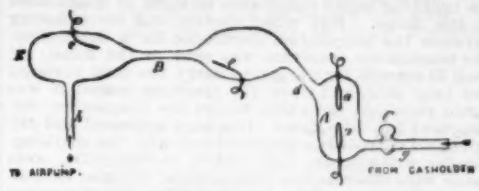
A. Flow Pipe. B. Reservoir.
C. Main Valve. D. Connecting Rod.
E. Air Engine. P. Compression Chamber.
G. Air Escape Valve. H. Float.
L. Air Chamber. M. Discharge Pipe.

THE SPECTROSCOPIC PROPERTIES OF DUST.*

THE suggestion that the auroral spectrum, the principal ray in the spectrum of nebulæ, and other rays of unknown origin, might be due to meteoric dust induced us to investigate the problem whether solid particles of sufficient minuteness would act like gaseous molecules in an electric discharge and become luminous with their characteristic special radiation. The dust we employed was that thrown off from the surface of various electrodes by a disruptive discharge, and it was carried forward into the tube of observation by a more or less rapid current of air or other gas.

The arrangement will be best understood from the annexed diagram, which represents a section of the glass vessel which was the principal part of the apparatus.

A represents a bulb in which were the electrodes, *a a*, to give the dust, connected by a widish tube, *d*, with the tube for observation, *B*. The end, *E*, was blown clear, so that the narrow part of *B* could be observed end-on. The electrodes, *e e*, were of platinum.



The tube, *g*, passing from *A* to the supply of gas, was fitted with a glass stopcock, *C*, for regulating the intake, and the tube, *h*, led from the distant end of *B* to the air pump. The air pump was a large one worked by a gas engine capable of keeping the pressure down to a few millimeters, even with a considerable leakage. Observations were made of the discharge in *B*, at various low pressures, sometimes with, and at other times without, a Leyden jar in circuit. The sparks in *A* were generally taken with a jar, and there was ample proof, if proof were needed, of the dust derived from the electrodes, since it formed a visible deposit in the tube, *d*, in the first bulb of *B*, and even on the end, *E*. The air or other gas passed into *A* was filtered through cotton wool to remove all dust before admission to the apparatus.

Various metals were used as electrodes in *A*, magnesium, iron, manganese, cadmium, fused calcium chloride, metallic sodium in a little glass cup on a platinum wire, and fragments of the Dhurmsala meteorite. But in no case could the rays of any of the substances employed be seen in the discharge through *B*, either when a Leyden jar was in circuit or not.

Incidentally, we found that magnesium electrodes were not so good as some of the other metals for these experiments, because the apparatus was never wholly free from traces of air, and lines or bright edges of bands of nitrogen fall very near the most characteristic lines of magnesium, and with small dispersion might easily be mistaken for them.

Air, hydrogen, carbon dioxide, and oxygen, were successively used as the gases passing through the apparatus, and at various pressures from 2 mm. up to 20, and, in some cases, up to 40 mm., but with the same result. No rays, due to the electrodes in *A*, could be detected in *B*. Even when one of the electrodes in *A* was sodium, and the sodium rays, orange, yellow, citron, green, and blue, were brilliant in the spectrum of *A*, not even the *D* lines could be detected in *B*. We should have expected that some of the traces of sodium *in the state of vapor* would have been carried by the stream of hydrogen into *B*. But it seems that it was not so, nor could the apparent absence of rays due to the dust be ascribed to mere faintness in their light, for we took photographs of the spectrum of *B*, and found that even lengthened exposures produced no evidence of rays due to the dust, nor could it be ascribed to the character of the discharge in *B*, for the discharge was varied. Sometimes *A* and *B* were in the same circuit, sometimes the discharge in *B* was from a separate coil, and even the powerful discharge from a large coil stimulated by a De Meritens magneto-electric machine was tried.

That abundance of dust was formed by the sparking in *A* was proved not only by the deposit in the tube, but by allowing the stream of gas at atmospheric pressure from the tube *h* (of course disconnected from the pump) to impinge on a flame, when the characteristic flame spectrum of the electrodes in *A* was at once manifest. When the gas used was hydrogen, and it was burnt in oxygen, the spectrum of the electrodes was particularly well seen, also when the gas was oxygen and led into a hydrogen flame.

* By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F. R. S., Jacksonian Professor, University of Cambridge. Received August 16, 1890.

That the dust was of extreme fineness and capable of being carried by a stream of gas to a great distance was proved as follows:

A stream of hydrogen, at ordinary pressure, was passed through the sparking tube, with magnesium electrodes, and then through more than 100 feet of metal tube in a coil, and, finally, burnt as it issued. Before the sparking began there were no signs of magnesium in the flame. But when sparks had been passing between the magnesium electrodes for a short time, the magnesium spectrum was seen in the flame. It took 55 seconds for the gas to carry the dust through the long pipe, and when the sparking ceased it was again about the same time before the magnesium disappeared from the flame. It always appeared and disappeared sharply in correspondence with the sparking. Similar experiments, but with a shorter tube, were made with other metals, iron, sodium, lithium, etc., always with like results. Also a current of oxygen was passed through the sparking tube and into a flame of hydrogen, and produced similar effects. Even aluminum, which does not usually show any part of its spectrum, when used as an electrode in a vacuous tube, gave, when sparked in oxygen, dust which, when carried into a hydrogen flame, showed the characteristic bands of alumina.

Considering that a sensible amount of dust was deposited in the bulbs of *B*, we should have expected that some would be deposited on the electrodes, *e e*, in that tube, and that the discharge from electrodes so coated would give the spectrum of the metal on their surface.

There is no doubt that when no discharge was taking place in *B*, the electrodes, *e e*, did receive their share of dust, and, if it had been allowed to accumulate so as to form a coherent crust, it would have given its characteristic spectrum on first passing sparks in *B*. But so long as the dust is loose, the passage of a discharge instantly clears the electrodes of all dust and seems to dispel all dust from the gas through which the discharge occurs. It is well known that an electric discharge in a vessel of air has the effect of clearing out of the air all the particles that serve as nuclei for the condensation of water, and we made several experiments with a view to determine whether a similar effect was produced on the dust in our tubes. The gas from the sparking tube was carried through a glass globe, and so on to the jet where it was burned. A wire connected with one pole of a Voss or Wimshurst electric machine projected into the interior of the globe, and a patch of tinfoil on the outside of the globe was connected with the other pole of the electric machine. So long as the Voss machine was not worked, the gas carried the dust from the sparking tube through the globe, and it was seen in the spectrum of the flame or simply in the color of the flame when lithium was one of the electrodes. But, on working the machine so as to produce a silent discharge inside the globe, the flame, in one or two seconds, suddenly ceased to show the spectrum of the dust, and in the case of the lithium lost its red color. When the machine was no longer worked, the spectrum or color speedily reappeared, to vanish again suddenly when the machine was started afresh. When a narrow tube, with a piece of a tinfoil outside and wire inside, was substituted for the globe, the like results ensued.

It appears, then, not only that dust, however fine, suspended in a gas will not act like gaseous matter in becoming luminous with its characteristic spectrum in an electric discharge, but that it is driven with extraordinary rapidity out of the course of the discharge. If, then, the spectrum of the aurora be due, not to the ordinary constituents of our atmosphere, but to adventitious matter from planetary space, we conclude that such matter must be in or must be brought into the gaseous state, or at least have its properties entirely altered from those it possesses at ordinary temperatures, before it becomes luminous in the electric discharge.—*Sidereal Messenger.*

[Continued from SUPPLEMENT, No. 788, page 12594.]

THE ELECTROMAGNET.*

By Professor SILVANUS P. THOMPSON, D.Sc., B.A., M.I.E.E.

IV.

MODIFICATIONS OF THE COIL AND PLUNGER.

IN one variety of the coil and plunger mechanism a second coil is wound on the plunger. Hjorth used this modification, and the same thing has been employed in several arc lamps. There is a series of drawings upon this wall depicting the mechanism of about a dozen different forms of arc lamp, all made by Messrs. Paterson & Cooper. In one of these there is a plunger with a coil on it drawn into a tubular coil, the current flowing successively through both coils. In another there are two separate coils in separate circuits, one of thin wire and one of thick, one being connected in series with the arc, and one in shunt.

DIFFERENTIAL COIL AND PLUNGER.

There is a third drawing here showing the arrangement, which was originally introduced by Siemens, wherein a plunger is drawn at one end into the coil that is in the main circuit, and at the other end into a coil that is in shunt. That differential arrangement has certain peculiar properties of which I must not now stop to speak in detail. It is obvious that where one core plunges its opposite ends into two coils, the magnetization will depend on both coils, and the resultant pull will not be simply the difference between the pull of the two coils acting each separately. There is, however, another differential arrangement, used in the Brockie-Pell and other arc lamps, in which there are two separate plungers attached to the two ends of a *seesaw* lever. In this case the two magnetizing actions are separate. In a third differential arrangement there is but one plunger and one tubular bobbin, upon which are wound the two coils, differentially, so that the action on the plungers is simply due to the difference between the ampere turns circulating in the two separate wires.

COIL AND PLUNGER COIL.

When one abandons iron altogether, and merely uses two tubular coils, one of wide diameter and another of narrower diameter, capable of entering into the former, and passes electric currents through both of them, if the currents are circulating in the same fashion through both of them, they will be drawing into one another. This arrangement has also been used in arc lamps. The parallel currents attract one another inversely, not as the square of the distance, but approximately as the distance. This is one of those little details about which it is as well to be clear. About once a year some kind friend from a distance writes to me pointing out a little slip that he says occurs in my book on electricity, in the passage where I am speaking about the attraction of parallel wires. I have made the terrible blunder of leaving out the word square; for I say the attraction varies inversely as the distance, and my readers are kind enough to correct me. Now when I wrote that passage I considered carefully what I had to write, and the attraction does not vary inversely as the square of the distance, because two parallel wires do not act on one another as two points. They act as two straight lines or two parallel lines, and the attraction between two parallel lines of current, or two parallel lines of magnetism, or two parallel lines of anything else that can attract, will not act inversely as the square, but simply inversely as the distance in between.

INTERMEDIATE FORMS.

Now this property of the coil and plunger of extending the range of action has been adopted in various ways by inventors whose object was to try and make electromagnets with a sort of intermediate range. For certain purposes it is desirable to construct an electromagnet which while having the powerful pull of the electromagnet, should have over its limited range of action a more equable pull, resembling in this respect the equalizing of range of the coil and plunger. Some of these intermediate forms of apparatus are shown in the following diagrams. Here (Fig. 65) is a peculiar

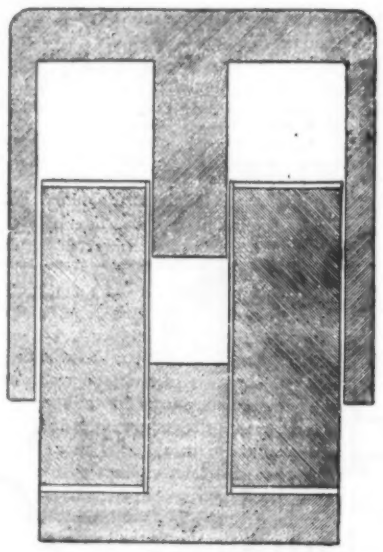


FIG. 65.—PLUNGER ELECTROMAGNET OF STEVENS AND HARDY.

form of electromagnet; it combines some of the features of the ironclad electromagnet with those of the movable plunger; it has a limited range of action, but is of great power over that range, owing to its excellent magnetic circuit. It was invented, in 1870, by Stevens and Hardy, for use in an electric motor for running sewing machines. A very similar form is used in Weston's arc lamp. A form of plunger electromagnet invented by Holroyd Smith in 1877 resembles Fig. 65 inverted; the coil being surrounded by an iron jacket, while a plunger, furnished at the top with an iron disk, descends down the central tube to meet the iron at the bottom.

Then there is another variety, of which I was able to show an example last week by the kindness of the Brush company, namely, the plunger electromagnet employed in the Brush arc lamps. A couple of tubular coils receive each an iron plunger, connected together by a yoke; while above, the magnetic circuit is partially completed by the sheet of iron which forms part of the inclosing box. You have here, also, the advantage of a fairly complete magnetic circuit, together with a comparatively long travel of the plunger and coil. It is a fair compromise between the two ways of working. The pull is not, however, in any of these forms, equal all along the whole range of travel; it increases as the magnetic circuit becomes more complete.

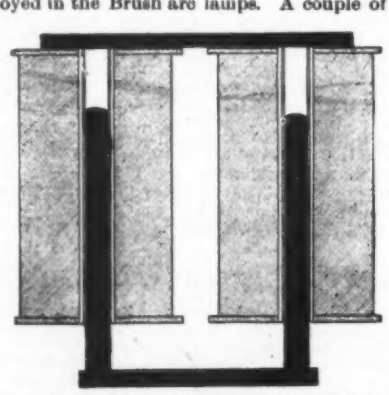


FIG. 66.—ELECTROMAGNET OF BRUSH ARC LAMP.

There are several other intermediate forms. For example, one inventor, Gaiser, employs a horse shoe electromagnet, the cores of which protrude a good distance beyond the coils, and for an armature he employs a piece of sheet iron, bent round so as to make at its ends two tubes, which inclose the poles, and are drawn down over them. Contrast with this design one of much earlier date by an engineer, Roloff, who made his electromagnets with iron cores not standing out, but sunk below the level of the ends of the coils, while the armature was furnished with little extensions that passed down into these projecting tubular ends of the coils. Some arc lamps have magnets of precisely that form, with a short plunger entering a tubular coil, and met half way down by a short fixed core inside the tube.

Here (Fig. 67) is one form of tubular ironclad electro-

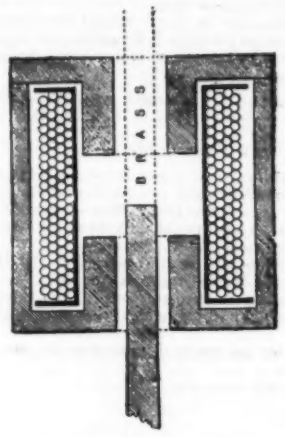


FIG. 67.—AYRTON AND PERRY'S TUBULAR IRONCLAD ELECTROMAGNET.

magnet that deserves a little more attention, being the one used by Messrs. Ayrton and Perry in 1882; a coil has an iron jacket round it, and also an annular iron disk across the top, and an annular iron disk across the bottom there being also a short internal tube of iron extending a little way down from the top, almost meeting another short internal tube of iron coming up from the bottom. The magnetic effect of the inclosed copper coil is concentrated within an extremely short space, between the ends of the internal tubes, where there is a wonderfully strong uniform field. The range of action you can alter just as you please in the construction by shortening or lengthening the internal tubes. An iron rod inserted below is drawn with great power and equality of pull over the range from one end to the other of these internal tubes.

ACTION OF MAGNETIC FIELD ON SMALL IRON SPHERE.

In dealing with the action of tubular coils upon iron cores, I showed how, when a very short core is placed in a uniform magnetic field, it is not drawn in either direction. The most extreme case is where a small sphere of soft iron is employed. Such a sphere, if placed in even the most powerful magnetic field, does not tend to move in any direction if the field is truly uniform. If the field is not uniform, then the iron sphere always tends to move from the place where the field is weak to a place where the field is stronger. A ball of bismuth or one of copper tends, on the contrary to move from a place where the field is strong to a place where the field is weaker. This is the explanation of the actions called "diamagnetic," which were at one time erroneously attributed to a supposed diamagnetic polarity opposite in kind to the ordinary magnetic polarity. A simple way of stating the facts is to say that a small sphere of iron tends to move up the *slope* of a magnetic field, with a force proportional to that slope; while (in air) a sphere of bismuth or one of copper tends, with a feeble force, to move down that slope. Any small piece of soft iron—a short cylinder, for example—shows the same kind of behavior as a small sphere. In some of Ayrton and Perry's coiled ribbon amperemeters and voltmeters, and in some of Sir William Thomson's current meters, this principle is applied.

SECTIONED COILS, WITH PLUNGER.

An important suggestion was made by Page, about 1850, when he designed a form of coil and plunger having a travel of indefinitely long range. The coiled tube, instead of consisting merely of one coil, excited simultaneously throughout its whole length by the current, was constructed in a number of separate sections or short tubes, associated together end to end, and furnished with means for turning on the electric current into any of the sections separately. Suppose an iron core to be just entering into any section, the current is turned on in that section, and as the end of the core passes through it, the current is then turned on in the section next ahead. In this way an attraction may be kept up along a tube of indefinite length. Page constructed an electric motor on this plan, which was later revived by Du Moncel, and again by Marcel Deprez in his electric "hammer."

WINDING OF TUBULAR COILS AND ELECTROMAGNETS.

The mention of this mode of winding in sections leads me to say a few final words about winding in general. All ordinary coils, whether tubular or provided with fixed cores, are wound in layers of alternate right handed and left handed spirals. In a preceding lecture I mentioned the mistaken notion, now disproved, that there is any gain in making all the spirals right handed or left handed. For one particular case there is an advantage in winding a coil in sections; that is to say, in placing partitions or *cloisons* at intervals along the bobbin, and winding the wire so as to fill up each of the successive spaces between the partitions before

* Lectures delivered before the Society of Arts, London, 1890. From the Journal of the Society.

passing on from one space to the next. The case in which this construction is advantageous is the unusual case of coils that are to be used with currents supplied at very high potentials. For when currents are supplied at very high potentials, there is a very great tension* exerted on the insulating material, tending to pierce it with a spark. By winding a coil in *cloisons*, however, there is never so great a difference of potentials between the windings on two adjacent layers as there would be if the layers were wound from end to end of the whole length of coil. Consequently, there is never so great a tension on the insulating material between the layers, and a coil so wound is less likely to be injured by the occurrence of a spark.

Another variety of winding has been suggested, namely, to employ in the coils a wire of graduated thickness. It has been shown by Sir William Thomson to be advantageous in the construction of the coils of galvanometers to use for the inner coils of small diameter a thin wire; then, as the diameter of the windings increases, a thicker wire; the thickest wire being used on the outermost layers; the gauge being thus proportioned to the diameter of the windings. But it by no means follows that the plan of using *graded wire*, which is satisfactory for galvanometer coils, is necessarily good for electromagnets. In designing electromagnets it is necessary to consider the means of getting rid of heat; and it is obvious that the outer layers are those which are in the most favorable position for getting rid of this heat. Experience shows that the under layers of coils of electromagnets always attain a higher temperature than those at the surface. If, therefore, the inner layers were to be wound with finer wire, offering higher resistance, and generating more heat than the outer layers, this tendency to overheating would be still more accentuated. Indeed, it would seem wise rather to reverse the galvanometer plan, and wind electromagnets with wires that are stouter on the inner layers and finer on the outer layers.

Yet another mode of winding is to employ several wires united in parallel, a separate wire being used for each layer, their anterior extremities being all soldered together at one end of the coil, and their posterior extremities being all soldered together at the other. Magnetically, this mode of winding presents not the slightest advantage over winding with a single stout wire of equivalent section. But it has lately been discovered that this mode of winding with *multiple wire* possesses one incidental advantage, namely, that its use diminishes the tendency to sparking which occurs at break of circuit.

EXTENSION OF RANGE BY OBLIQUE APPROACH.

I now pass to the means which have been suggested for extending the range of motion, or of modifying its amount at different parts of the range, so as to equalize the very unequable pull.

There are several such devices, some electrical, others purely mechanical, others electro-mechanical. First there is an electrical method. Andre proposed that as soon as the armature has begun to move nearer, and comes to the place where it is attracted more strongly, it is automatically to make a contact, which will shunt off part of the current and make the magnetism less powerful. Burnett proposed another means: a number of separate electromagnets acting on one armature, but as the latter approached, these electromagnets were one after the other cut out of the circuit. I need not say the advantages of that method are very hypothetical. Then there is another method which has been used many times with very great success, the method of allowing the motion of the armature to occur obliquely, it being mechanically constrained so as to move past instead of toward the pole. When the armature is pulled thus obliquely, the pull will be distributed over a definite wider range. Here is a little motor made on that very plan. A number of pieces of iron set on the periphery of a wheel are successively attracted up sideways. An automatic device breaks the circuit as every piece of iron comes near, just at the moment when it gets over the poles, and the current being cut off, it flies on beyond and another piece comes up, is also attracted in the same way, and then allowed to pass. A large number of toy motors have been made from time to time on this plan. I believe Wheatstone was the first to devise the method of oblique approach about the year 1841. He made many little electromagnetic motors, the armatures of which were in some cases solid rims of iron arranged as a sort of wheel, with two or more zigzag internal teeth, offering oblique surfaces to the attraction of an electromagnet. Such little motors are often now used for spinning Geissler's vacuum tubes. In these motors the iron rim is fixed, and the electromagnet rotates. The pole of the electromagnet finds itself a certain distance away from the iron ring. It tries to get nearer. The only way it can get nearer is by swinging round, and so it gradually approaches, and as it approaches the place where it is nearest to the internal projection of the rim the current is cut off, and it swings further. This mode may be likened to a cam in a mechanical movement. It is, in fact, nothing else than an *electromagnetic cam*. There are other devices too, which are more like electromagnetic *linkages*. If you curve the poles or shape them out you may obtain actions which are like that of a wedge on an inclined plane. There is an electromagnet in one of Paterson and Cooper's arc lamps wherein the pole piece, coming out below the magnet, has a very peculiar shape, and the armature is so pivoted with respect to the magnet that as the armature approaches the core as a whole, its surface recedes from that of the pole piece, the effect being that the pull is equalized over a considerable range of motion. There is a somewhat similar device in De Puydt's pattern of arc lamp.

Here is another device for oblique approach, made by Froment. In the gap in the circuit of the magnet a sort of iron wedge is put in, which is not attracted squarely to either face, but comes in laterally between guides. Another of Froment's equalizers, or distributors, consists of a parallel motion attachment for the armature, so that oblique approach may take place without actual contact. Here, Fig. 68, is another mechanical method of equalizing devised by Froment, and used by Le Roux. You know the Stanhope lever, the object of which is to transform a weak force along a considerable range into a powerful force at short range. Here we use it backward. The armature itself, which is attracted with a powerful force at short range, is attached to the lower end of the Stanhope

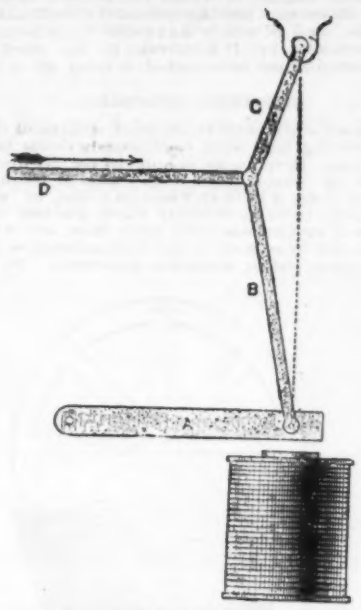


FIG. 68.—FROMENT'S EQUALIZER WITH STANHOPE LEVER.

lever, and the arm attached to the knee of the lever will deliver a distributed force over quite a different range. One way, not of equalizing the actual motion over the range, but of counterbalancing the variable attractive force, is to employ a spring instead of gravity to control the armature. So far back as 1838, Edward Davy, in one of his telegraphic patents, described the use of the spring (Fig. 69) to hold back the ar-

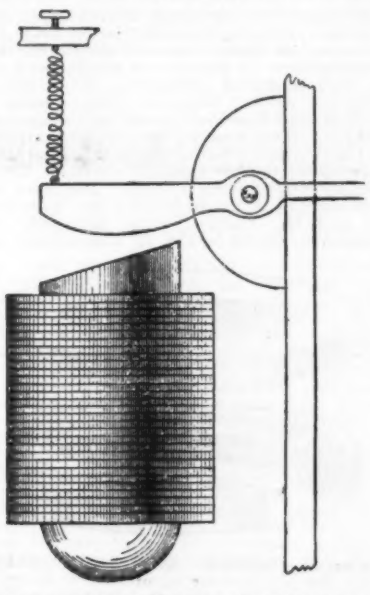


FIG. 69.—DAVY'S MODE OF CONTROLLING ARMATURE BY SPRING.

mature. Davy preceded Morse in the use of a spring to pull back the armature. There is a way of making a spring act against an armature more stiffly as the pull gets greater. In this method there is a spring with various set screws set up against it, and which come into action at different ranges, so as to alter the stiffness of the spring, making it virtually stiffer as the armature approaches the poles. Yet another method is to employ, as the famous conjurer, Robert Houdin did, a rocking lever. Fig. 70 depicts one of

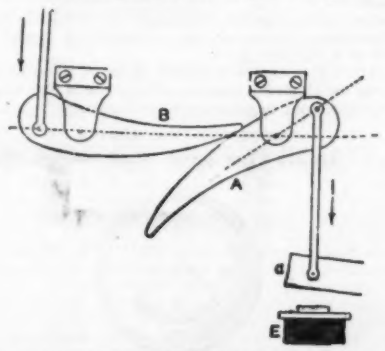


FIG. 70.—ROBERT HOUDIN'S EQUALIZER.

Robert Houdin's equalizers. The pull of the electromagnet on the armature acts on a curved lever which works against a second one; the point of application of force between the one and the other altering with their position. When the armature is far away from the pole, the leverage of the first lever on the second lever is great. When the armature gets near, the leverage of the first lever on the second is comparatively small. This employment of the *rocking lever* was adopted from Houdin by Duboscq, and put into the Duboscq arc lamp, where the regulating mechanism at the bottom of the lamp contains a rocking lever. Here upon the lecture table is a Duboscq's arc lamp. In this pattern (Fig. 71), one lever, B, which is curved,

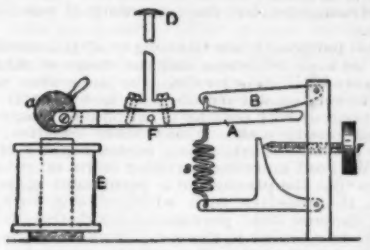


FIG. 71.—MECHANISM OF DUBOSCQ'S ARC LAMP.

plays against another, A, which is straight. A similar mechanism is used for equalizing the action in the Serrin arc lamp, where one of the springs that holds up the jointed parallelogram frame is applied at the end of a rocking lever to equalize the pull of the regulating electromagnet. In this lamp there is also introduced the principle of oblique approach; for the armature of the electromagnet is not allowed to travel straight toward the poles of the magnet, but is pulled up obliquely past it.

Another device for equalizing the pull was used by Wheatstone in his step by step telegraph in 1840. A hole is pierced in the armature, and the end of the core is formed into a projecting cone, which passes through the aperture of an armature, thereby securing a more equable force and a longer range. The same device has reappeared in recent years in the form of electromagnet used in the Thomson-Houston arc lamp, and in the automatic regulator of the same firm.

POLARIZED MECHANISM—USES OF PERMANENT MAGNETS.

We must now turn our attention to one class of electromagnetic mechanism which ought to be carefully distinguished from the rest. It is that class in which, in addition to the ordinary electromagnet, a permanent magnet is employed. Such an arrangement is generally referred to as a *polarized mechanism*. The objects for which the permanent magnet is introduced into the mechanism appear to be in different cases quite different. I am not sure whether this is clearly recognized, or whether a clear distinction has ever been drawn between three entirely separate purposes in the use of a permanent magnet in combination with an electromagnet. The first purpose is to secure unidirectionality of motion; the second, is to increase the rapidity of action and of sensitiveness to small currents; the third, to augment the mechanical action of the current.

(*a.*) *Unidirectionality of Motion.*—In an ordinary electromagnet it does not matter which way the current circulates. No matter whether the pole is north or south, the armature is pulled, and on reversing the current the armature is also pulled. There is a rather curious old experiment which Sturgeon and Henry showed, that if you have an electromagnet with a big weight hanging on it, and you suddenly reverse the current, you reverse the magnetism, but it still holds the weight up, it does not drop. It has not time to drop before the magnet is charged up again with magnetic lines the other way on. Whichever way the magnetism traverses the ordinary soft iron electromagnet, the armature is pulled. But if the armature is itself a permanent magnet of steel, it will be pulled when the poles are of one sort, and pushed when the poles are reversed—that is to say, by employing a *polarized armature* you can secure unidirectionality of motion in correspondence with the current. One immediate application of this fact for telegraphic purposes is that of duplex telegraphy. You can send two messages at the same time and in the same direction to two different sets of instruments, one set having ordinary electromagnets, with a spring behind the armature of soft iron, which will act simply independently of the direction of the current, depending only on its strength and duration, and another set having electromagnets with polarized armatures, which will be affected, not by the strength of the current, but by the direction of it. Accordingly, two completely different sets of message may be sent through that line in the same direction at the same time.

Another mode of constructing a polarized device is to attach the cores of the electromagnet to a steel magnet, which imparts to them an initial magnetization.

Such initially magnetized electromagnets were used by Brett in 1848 and by Hjorth in 1850. A patent for a similar device was applied for in 1870 by Sir William Thomson, and refused by the patent office. In 1871 S. A. Varley patented an electromagnet having a core of steel wires united at their ends.

Wheatstone used a polarized apparatus consisting of an electromagnet acting on a magnetized needle. He patented, in fact, in 1845, the use of a needle permanently magnetized to be attracted one way or the other between the poles of an electromagnet. Sturgeon has described the very same device in the *Annals of Electricity* in 1840. Gloesner claims to have invented the substitution of permanent magnets for mere armatures in 1842.

In using polarized apparatus it is necessary to work, not with a simple current that is turned off and on, but with reversed currents. Sending a current one way will make the moving part move in one direction. Reversing the current makes it go over to the other side. The mechanism of that particular kind of electric bell that is used with magneto-electric calling apparatus furnishes an excellent example of a polarized construction.

With these bells no battery is used, but there is a

* The tension on the insulating material, tending to pierce it with a spark, is proportional to the square of the difference of potentials (per unit thickness) to which the insulating material is subject. It is incorrect to talk ab ut the tension of the conductor, or about the tension of the current; for the tension or electric stress is always an action affecting the dielectric or insulating material.

little alternate current dynamo, worked by a crank. The alternate currents cause the pivoted armature in the bell to oscillate to right and left alternately, and so throw the little hammer to and fro between the two bells.

(*b.*) *Rapidity and Sensitiveness of Action.*—For relay work polarized relays are often employed, and have been for many years. Here on the table is one of the post office pattern of standard relay, having a steel magnet to give magnetism permanently to a little tongue or armature which moves between the poles of an electromagnet that does the work of receiving the signals.

In this particular case the tongue of polarized relay works between two stops, and the range of motion is made very small in order that the apparatus may respond to very small currents. At first sight it is not very apparent why putting a permanent magnet into a thing should make it any more sensitive. Why should permanent magnetism secure rapidty of working? Without knowing anything more, inventors will tell you that the presence of a permanent magnet increases the rapidity with which it will work. You might suppose that permanent magnetism is something to be avoided in the cores of your working electromagnets, otherwise the armatures would remain stuck to the poles when once they had been attracted up. Residual magnetism would, indeed, hinder the working unless you have so arranged matters that it shall be actually helpful to you. Now for many years it was supposed that permanent magnetism in the electromagnet was anything but a source of help. It was supposed to be an unmitigated nuisance, to be got rid of by all available means, until in 1855 Hughes showed us how very advantageous it was to have permanent magnetism in the cores of the electromagnet.

Here, Fig. 51, is the drawing of Hughes' magnet to which I referred in Lecture III. A compound permanent magnet of horse-shoe shape is provided with coils on its pole pieces, and there is a short armature on the top attached to a pivoted lever and a counteracting spring.

The function of this arrangement is as follows: That spring is so set as to tend to detach the armature, but the permanent magnet has just enough magnetism to hold the armature on. You can, by screwing up a little screw behind the spring, adjust these two contending forces, so that they are in the nicest possible balance. The armature held on by the magnetism, and the spring just not able to pull it off. If, now, when these two actions are so nearly balanced you send an electric current round the coils, if the electric current goes one way round it just weakens the magnetism enough for the spring to gain the victory, and up goes the armature. This apparatus then acts by letting the armature off when the balance is upset by the electric current, and it is capable of responding to extremely small currents. Of course, the armature has to be put on again mechanically, and in Hughes' typewriting telegraph instruments it is put on mechanically between each signal and the next following one. The arrangement constitutes a distinctive piece of electromagnetic mechanism.

(*c.*) *Augmenting Mechanical Action of Current.*—The third purpose of a permanent magnet, to secure a greater mechanical action of the varying current, is closely bound up with the preceding purpose of securing sensitiveness of action. It is for this purpose that it is used in telephone receivers. It increases the mechanical action of the current, and therefore makes the receiver more sensitive. For a long time this was not at all clear to me, indeed I made experiments to see how far it was due to any variation in the magnetic permeability of iron at different stages of magnetization, for I found that this had something to do with it, but I was quite sure it was not all. Prof. George Forbes gave me the clew to the true explanation. It lies in the law of traction with which you are now familiar, that the pull between a magnet and its armature is proportional to the square of the number of magnetic lines that come into action. If we take $\mathbf{N}$, the number of magnetic lines that are acting through a given area, then to the square of that the pull will be proportional. If we have a certain number of lines, $\mathbf{N}$, coming permanently to the armature, the pull is proportional to $\mathbf{N}^2$. Suppose the magnetism now to be altered, say made a little more, and the increment be called $d\mathbf{N}$, so that the whole number is now

$$\mathbf{N} + d\mathbf{N}$$

The pull will now be proportional to the square of that quantity. It is evident that the motion will be proportional to the difference between the former pull and the latter pull. So we will write out the square of $\mathbf{N} + d\mathbf{N}$, and the square of $\mathbf{N}$ and take the difference.

Increased pull, proportional to	$\mathbf{N}^2 + 2\mathbf{N}\cdot d\mathbf{N} + d\mathbf{N}^2$
Initial pull, proportional to	$\mathbf{N}^2$
Subtracting, difference is	$2\mathbf{N}\cdot d\mathbf{N} + d\mathbf{N}^2$

We may neglect the last term, as it is small compared with the other. So we have, finally, that the change of pull is proportional to $2\mathbf{N}\,d\mathbf{N}$. The alteration of pull between the initial magnetism and the initial magnetism with the additional magnetism we have given to it, turns out to be proportional, not simply to the change of magnetism, but also to the initial number, $\mathbf{N}$, that goes through it to begin with.

The more powerful the pull to begin with, the greater is the change of pull when you produce a small change in the number of magnetic lines. That is why you have this greater sensitiveness of action when using Hughes electromagnets, and greater mechanical effect as the result of applying permanent magnetism to the electromagnets of telephone receivers.

ELECTROMAGNETIC MECHANISM.

There are some other kinds of electromagnetic mechanism to which I must briefly invite your attention, as forming an important part of this great subject. Of one of these the mention of permanent magnets reminds me.

MOVING COIL IN PERMANENT MAGNETIC FIELD.

A coil traversed by an electric current experiences mechanical forces if it lies in a magnetic field, the force being proportional to the intensity of the field.

Of this principle the mechanism of Sir W. Thomson's siphon recorder is a well known example. Also those galvanometers which have for their essential part a movable coil suspended between the poles of a permanent magnet, of which the earliest example is that of Robertson (*see Encyclopædia Britannica*, ed. viii., 1855), and of which Maxwell's suggestion, afterward realized by D'Arsonval, is the most modern. Siemens has constructed a relay on a similar plan.

MAGNETIC ADHERENCE.

There are a few curious pieces of apparatus devised for increasing adherence electromagnetically between two things. Here is an old device of Nicklès, who thought he would make a new kind of rolling gear. Whether it was a railway wheel on a line, or whether it was going to be an ordinary wheel gearing, communication of motion was to be made from one wheel to another, not by cogs or by the mere adherence of ordinary friction, but by magnetic adherence. In Fig. 72

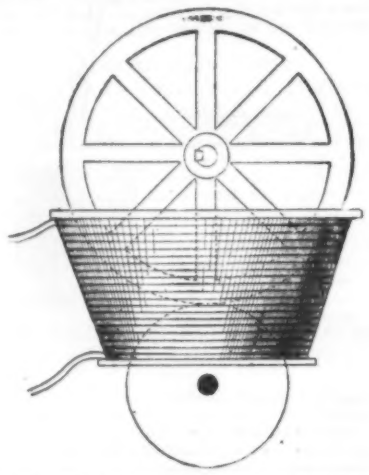


FIG. 72.—NICKLE'S MAGNETIC FRICTION GEAR.

there are shown two iron wheels rolling on one another, with a sort of electromagnetic jacket around them, consisting of an electric current circulating in a coil, and causing them to attract one another and stick together with magnetic adherence. In Nicklès' little book on the subject there are a great number of devices of this kind described, including a magnetic brake for braking railway wagons, engines, and carriages, applying electromagnets either to the wheels or else to the line, to stop the motion whenever desired. The notion of using an electromagnetic brake has been revived quite recently in a much better form by Professor G. Forbes and Mr. Timmis, whose particular form of electromagnet, shown in Fig. 73, is peculiarly interest-

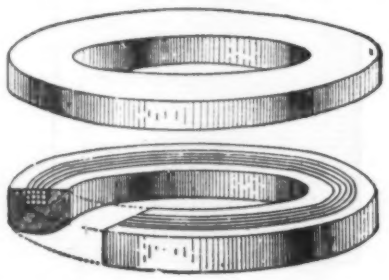


FIG. 73.—FORBES' ELECTROMAGNET.

ing, being a better design than any I have ever seen for securing powerful magnetic traction for a given weight of iron and copper. The magnet is a peculiar one; it is represented here as cut away to show the internal construction. There is a sort of horse shoe made of one grooved rim, the whole circle of coil being laid embedded in the groove. The armature is a ring which is attracted down all round, so that you have an extremely compact magnetic circuit around the copper wire at every point. The magnet part is attached to the frame of the wagon or carriage, and the ring armature is attached to the wheel or to its axis. On switching on the electric current the rim is powerfully pulled, and braked against the polar surface of the electromagnet.

Forbes' arrangement appears to be certainly the best yet thought of for applying a magnetic brake to the wheels of a railway train.

Another, but quite distinct, piece of mechanism depending on electromagnetic adherence is the magnetic *clutch* employed in Gülcher's arc lamp.

REPULSION MECHANISM.

Then there are a few pieces of mechanism which depend on repulsion. In 1850 a little device was patented by Brown & Williams, consisting, as shown in Fig. 74,

FIG. 74.—ELECTROMAGNETIC MECHANISM WORKING BY REPULSION.

of an electromagnet which repelled part of itself. The coil is simply wound on a hollow tube, and inside the coil is a piece, B, of iron, bent as the segment of a cylinder to fit in, going from one end to the other. Another little iron piece, A, also shaped as the segment of a tube, is pivoted in the axis of the coil. When these are magnetized one tends to move away from the other, they being both of the same polarity. Of late there have been many ampere-meters and volt-meters made on this plan of producing repulsion between the parallel cores.

Here (Fig. 75) is another device of recent date, due

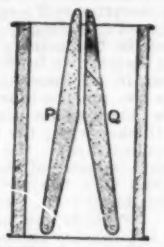


FIG. 75.—REPULSION BETWEEN TWO PARALLEL CORES.

to Maikoff and De Kabath. Two cores of iron, not quite parallel, pivoted at the bottom, pass up through a tubular coil. When both are magnetized, instead of attracting one another, they open out; they tend to set themselves along the magnetic lines through that tube. The cores being wide open at the bottom, tend to open also at the top.

ELECTROMAGNETIC VIBRATORS.

Then there is a large class of mechanisms about which a whole chapter might be written, namely, those in which vibration is maintained electromagnetically. The armature of an electromagnet is caused to approach and recede alternately with a vibrating motion, the current being automatically cut off and turned on again by a self-acting brake. The electromagnetic vibrator is one of the cleverest things ever devised. The first vibrating electromagnetic mechanism ever made was exhibited here in this room in 1824 by its inventor, an Englishman named James Marsh. It consisted of a pendulum vibrating automatically between the poles of a permanent magnet. Later, a number of other vibrating devices were produced by Wagner, Neef, Froment and others. Most important of all is the mechanism of the common electric trembling bell, invented by a man whose very name appears to be quite forgotten—John Mirand. How many of the millions of people who use electric bells know the name of the man who invented it? John Mirand, in the year 1850, put the electric bell practically into the same form in which it has been employed from that day to this. The vibrating hammer; the familiar push button; the indicator or annunciator, are all of his devising, and may be seen depicted in the specification of his British patent just as they came from his hand.

Time alone precludes me from dealing minutely with these vibrators, and particularly with the recent work of Mercadier and that of Langdon-Davies, whose researches have put a new aspect on the possibilities of harmonic telegraphy. Langdon-Davies' rate governor is the most recent and perfect form of electromagnetic vibrator.

INDICATOR MOVEMENTS.

Upon the table here are a number of patterns of electric bells, and a number also of the electromechanical movements or devices employed in electric bell work, some of which form admirable illustrations of the various principles that I have been laying down. Here is an iron-clad electromagnet; here a tripolar magnet; here a series of pendulum motions of various kinds; here is an example of oblique pull; here is Jensen's indicator, with lateral pull; here is Moseley's indicator, with a coil and plunger, ironclad; here is a clever device in which a disk is drawn up to better the magnetic circuit. Here, again, is Thorpe's semaphore indicator, one of the neatest little pieces of apparatus, with a single central core surrounded by a coil, while a little strip of iron coming round from behind serves to complete the circuit all save a little gap. Over the gap stands that which is to be attracted, a flat disk of iron, which, when it is attracted, unlatches another disk of brass, which forthwith falls down. It is an extremely effective, very sensitive, and very inexpensive form of annunciator. The next two are pieces of polarized mechanism having a motion directed to one side or the other, according to the direction of the current. From the back board projects a small straight electromagnet. Over it is pivoted a small arched steel magnet, permanently magnetized, to which is attached a small signal lever bearing a red disk. If there is a current flowing one way, then the magnet that straddles over the pole of the electromagnet will be drawn over in one direction. If I now reverse the current, the electromagnet attracts the other pole of the curved magnet. Hence this mechanism allows of an electrical replacement, without compelling the attendant to walk up to the indicator board. The polarized apparatus for indicators has this advantage, that you can have electrical as distinguished from mechanical replacement.

THE STUDY OF ELECTROMAGNETIC MECHANISM.

The rapid survey of electromagnetic mechanism in general has necessarily been very hurried and imperfect. The study of it is just as important to the electric engineer as is the study of mechanical mechanism to the mechanical engineer. Incomplete as is the present treatment of the subject, it may sufficiently indicate to other workers useful lines of progress, and so fitly be appended to these lectures on the electromagnet. In a very few years we may expect the introduction into all large engineering shops of electromagnetic tools. On a small scale, for driving dental appliances, electromagnetic engines have long been used. Large machine tools electromagnetically worked have already begun to make their appearance. Some such were shown at the Crystal Palace, in 1881, by Mr. Latimer Clark, and more recently, Mr. Rowan, of Glasgow, has devised a number of more developed forms of electromagnetic tools.

SUPPRESSION OF SPARKING.

It now remains for me to speak briefly of the suppression of sparks. There are some half dozen different ways of trying to get rid of the sparking that occurs in the breaking of an electric circuit whenever there are electromagnets in that circuit. Many attempts have been made to try and get rid of this evil. For instance, one inventor employs an air blast to blow out the spark just at the moment it occurs. Another causes the spark to occur under a liquid. Another wipes it out with a brush of asbestos cloth that comes immediately behind the wire and rubs out the spark. Another puts on a condenser to try and store up the energy. Another tries to put on a long thin wire or a high resistance of liquid, or something of that kind, to provide an alternate path for the spark, instead of jumping across the air and burning the contacts. There exist some half score, at any rate, of that kind of device. But there are devices that I have thought it worth while to examine and experiment upon, because they depend merely upon the mode of construction adopted in the building of the electromagnet, and they have each their own qualities. I have here five straight electromagnets, all wound on bobbins the same size, for which we shall use the same iron core and the same current for all. They are all made, not only with bobbins of the same size, but their coils consist as nearly as possible of the same weight of wire. The first one is wound in the ordinary way, the second one has a sheath of copper wound around the interior of the bobbin before any wire is put on. This was a device, I believe, of the late Mr. C. F. Varley, and is also used in the field magnets of Brush dynamos. The function of the copper sheath is to allow induced currents to occur, which will retard the fall of magnetism, and damp down the tendency to spark. The third one is an attempt to carry out that principle still further. This is due to an American of the name of Paine, and has been revived of late years by Dr. Aron, of Berlin. After winding each layer of the coil, a sheath of metal foil is interposed so as to kill the induction from layer to layer. The fourth one is the best device hitherto used, namely, that of differential winding, having two coils connected so that the current goes opposite ways. When equal currents flow in both circuits there is no magnetism. If you break the circuit of either of the two wires, the core at once becomes magnetized. You get magnetism on breaking, you destroy magnetism on making the circuit; it is just the inverse case to that of the ordinary electromagnet. There the spark occurs when magnetism disappears, but here, since the magnetism disappears when you make the circuit, you do not get any spark at make, because the circuit is already made. You do not get any at break, because at break there is no magnetism. The fifth and last of these electromagnets is wound according to a plan devised by Mr. Langdon-Davies, to which I alluded in the middle of this lecture, the bobbin being wound with a number of separate coils in parallel with one another, each layer being a separate wire, the separate ends of all the layers being finally joined up. In this case there are fifteen separate circuits; the time constants of them are different, because, owing to the fact that these coils are of different diameters, the coefficient of self-induction of the outer layers is rather less, and their resistance, because of the larger size, rather greater than those of the inner layers. The result is that instead of the extra current running out all at the same time, it runs out at different times for these fifteen coils. The total electromotive force of self-induction never rises so high, and it is unable to jump a large air gap, or give the same bright spark as the ordinary electromagnet would give. We will now experiment with these coils. The differential winding gives absolutely no spark at all, and second in merit comes No. 5, with the multiple wire winding. Third in merit comes the coil with intervening layers of foil. The fourth is that with copper sheath. Last of all, the electromagnet with ordinary winding.

CONCLUSION.

Now let me conclude by returning to my starting point—the invention of the electromagnet by William Sturgeon. Naturally you would be glad to see the counterfeit presentment of the features of so remarkable a man, of one so worthy to be remembered among distinguished electricians and great inventors. Your disappointment cannot be greater than mine when I tell you that all my efforts to procure a portrait of the deceased inventor have been unavailing. Only this I have been able to learn as the result of numerous inquiries; that an oil painting of him existed a few years ago in the possession of his only daughter, then resident in Manchester, whose address is now, unfortunately, unknown. But if his face must remain unknown to us, we shall none the less proudly concur in honoring the memory of one whose presence once honored this hall wherein we are met, and whose work has won for him an imperishable name.

Prof. Thompson, in replying to the vote of thanks, stated that if any of those present could assist him in discovering what had become of the portrait of William Sturgeon, or in gleaning any particulars with regard to John Mirand, he should be much indebted to them if they would communicate with him.

THE MIGRATION OF THE SALMON.

THERE is no one who has not heard the migrations of the salmon spoken of. Judging from the agreement that exists on this subject among naturalists, the question might be regarded as perfectly known.

No matter what work on natural history we may open that speaks of the habits of the salmon, we shall, in substance, read therein the following:

Toward the beginning of spring, the salmon, which has passed the winter in the sea, approaches the mouths of rivers, and, after stopping there for a certain length of time, as if to habituate itself to fresh water, enters the river and ascends it to a greater or less distance in order to spawn.

This phenomenon has been called the ascent of the salmon, and it is said that at this epoch the male exhibits bright and attractive colors, having donned its "wedding attire."

This is the epoch, too, at which the flesh of the fish is most savory. After the spawning is over, the fish return to the sea. They are then exhausted and exhibit a dull color, and their flesh is no longer edible.

Such are the *classic* ideas adopted by everybody, reproduced in all books, perpetuated by the descriptions of authors who have *seen* salmon make their nests, deposit their eggs, etc.

Such is the *official* history of the reproduction of the salmon, upon which in particular is based the law that forbids the taking of this fish during the season of spawning, that is to say, from the 20th of October to the 1st of February.

Now all this history is absolutely false. Among the salmon that ascend a river, we never find reproductive individuals, for the good reason that at this epoch their genital organs are scarcely developed. The demonstration of this fact is one of the simplest of things, and yet it has never occurred to any of the naturalists who have occupied themselves with the salmon to ascertain the condition of the genital organs of the animals which they speak of as being clad in their "wedding attire." The history of the reproduction of the salmon is quite different from what it has hitherto been thought to be, and it is due to the researches of Mr. J. Kunstler, a learned zoologist, of Bordeaux, who has studied the habits of the salmon of the Dordogne, that light has finally been shed upon a question which interests the fishing industry to so high a degree.

Let us in the first place briefly describe the evolution of the salmon. During the first year of their existence, salmon resemble young trout, and are of a dull gray color, with fifteen or eighteen blackish bands upon the sides. In this state they are designated by the English as *parrs*. At the end of a year, they become *smolts* or *salmonets*, that is to say, the body assumes a metallic luster upon the back and exhibits eight or ten large bright blue spots upon the sides, while the belly is of a beautiful pearly white. The smolts, like the parrs, live in fresh water, but, in order to finish their evolution, they need a sojourn in the sea. To this effect, they collect in groups, descend the stream and enter the ocean, where they disappear for seven or eight weeks. At the end of this time, they reappear in the form of *grilses* or young salmon. The difference between these and the smolts is such that one would never have supposed that they represented two stages of the development of the same fish, had not the idea occurred to attach a tag to a certain number of individuals. In fact, the smolt is but from five to eight inches in length, while upon becoming a grilse, after remaining two months in the ocean, it weighs four and a half pounds.

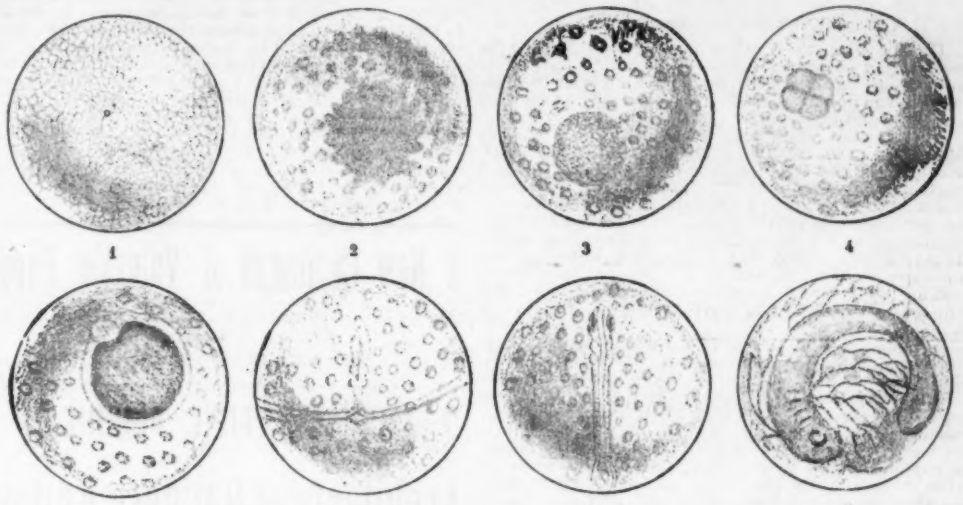


FIG. 1.—PRINCIPAL PHASES OF DEVELOPMENT OF THE SALMON.

1. Ovarian egg before the dehiscence of the follicle. The micropyle is seen above the cicatriculos. 2. Beginning of the concentration of the germ. 3. Appearance of the first sulcus of segmentation. 4. Segmentation into four parts. 5. Appearance of the embryo. 6. The blastoderm covers half of the vitellus. 7. The eyes and auditory vesicles formed, and the blastoderm on the point of completely covering the vitellus. 8. Embryo shortly before being hatched.

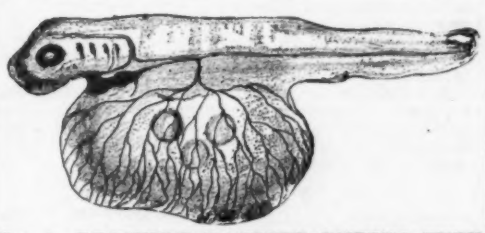


FIG. 2.—RECENTLY HATCHED EMBRYO, WITH VITELLINE SACK ATTACHED.

It is these young salmon and others more aged that, starting from a certain epoch, ascend water courses for the purpose, it has hitherto been supposed, of spawning. But there is nothing in this. When we study the manner in which the ascent is made (at least in the Dordogne), we remark that the largest salmon ascend first, then come gradually, and always in series, smaller and smaller fish. The first ascend the river in November or December, and weigh from 20 to 30 pounds; then in January and February arrive fish of from 15 to 20 pounds, and so on up to July, when the salmon weigh but from 5 to 7 pounds. Now all these salmon, which came from the sea, have tender and savory flesh, and their colors are bright. They have donned their "wedding attire" in order to spawn, say the old authors.

But such a hypothesis the most elementary dissection suffices to refute, since, as Kunstler has shown, the eggs at the time of the ascent (and whatever be the size of the salmon) are no larger than the head of a pin, and are perfectly colorless.

Now, in measure as the salmon ascends the river, its flesh progressively loses its flavor. This is a fact that has long been known, but this loss is also (and no one had ever suspected it) the beginning of a metamorphosis of which the last state is that of *becard* (female salmon). In fact, having reached the end of its journey, the fish loses weight, its brilliant colors disappear, it becomes covered with greenish spots, and, concurrently with these transformations, the sexual products develop, the eggs become larger and progressively take on a color. The salmon becomes thus transformed into a *becard*, a dull colored being of which the leanness is striking, and *which is the reproductive individual* In order to effect this metamorphosis, the salmon betake themselves to the deep parts of the river.

They hide in holes in deep water, sheltered from the too intense heat of summer, and remain concealed there for several months—the period necessary for their complete transformation into *becards* and for the maturation of the sexual products. Whatever be their size at the time of their migration, all salmon thus go to lie in the deep depressions of the river. The successive ascents all proceed in the same manner, and the fishermen capture nothing but newly arrived fish, that is to say, those that are smaller and smaller. But when we explore the deep water of the river, the result is wholly different.

Thus, Kunstler, in exploring the Dordogne in the month of July, a time at which fishing on the whole river gave exclusively salmon of but 5 or 8 pounds, made the surprising catch of fish of all sizes, but so modified in appearance as to have more or less resemblance to *becards*.

Now, salmon that are unmistakably *becards* are met with in the Dordogne only during the second half of October and the first fortnight of November. We may therefore conclude from this that the salmon spawns from the end of September to the fifteenth of November.

At this epoch, the operation is finished, and it is after having deposited their eggs that the *becards* run out to sea again to acquire fresh strength and to assume again the characters of the salmon properly so called.

In fact, the reproduction of the salmon is biennial, and not annual, as we have always supposed and been taught.

The ascending salmon of progressively smaller size are fished for from autumn up to the following summer.

The large salmon reascend in autumn, and pass the entire summer in the river, but they are not any sooner in a state to spawn than the smaller fish that have arrived several months after them. The young therefore have the innate faculty of more rapidly acquiring sexual maturity. The salmon then pass the entire summer in the river, concealed in the deep depressions of its bed, and become transformed therein into reproductive individuals or *becards*, which are no longer edible. After spawning, they proceed to the sea again, in order to pass the winter and following summer therein.

FIG. 3.—YOUNG SALMON AFTER ABSORPTION OF THE UMBILICAL VESICLE.

Let us now see what are the practical conclusions to be drawn from the facts that we have just given. The regulation now in force in France prohibits salmon fishing from the 20th of October to the 1st of February, this being for the purpose of protecting the reproduction of these fish. This regulation was founded upon the data furnished by the older naturalists as to the time of the salmon's spawning.

But, as the habits of these fish are not at all what they have hitherto been thought to be, this regulation absolutely fails of the object aimed at. A reform of this legislation, based upon the exact knowledge that we now possess as to the habits of the fish, is, therefore, absolutely necessary. Fishing ought not to be

prohibited starting from the 20th of October, but from the 1st of September, when the salmon has partially undergone its sexual metamorphosis. In return, fishing should be permitted from the 15th of November, the time at which the *becards* have finished spawning, and when the fine salmon are beginning to ascend the rivers. Moreover, these limits, indicated by Kunstler for the Dordogne, should vary with the climate, temperature, etc. Unfortunately, in France, we are accustomed to see *rational* reforms made so slowly that we can scarcely hope to see this state of things change for a long time to come. It is the interests of fishermen especially that are injured by this superannuated legislation, for the salmon protects its own self in a manner, since the reproductive individual (*becard*) is not edible. Poor fishermen themselves have no use for it, and, owing to this fact, fishing is suspended with the beginning of August.—*Le Naturaliste.*

"ALUMININ."

(HYDRATE OF ALUMINA.)

UNDER this name a writer in the *Papier Zeitung* describes the various methods of preparing pastes consisting substantially of hydrate of alumina which are used in the preparation of paste colors. The following is an abstract of the article:

The alumina paste may be obtained of a more or less white color, depending on the kind of raw material used, by the decomposition of an alumina salt and carbonate of soda, etc. The precipitated hydrate of alumina thus obtained is employed in the manufacture of variegated paper (Buntpapier). It is used for diluting colors, such as ultramarine, to the required shade. It may also be mixed with wax or glue solutions, like ordinary paste colors, and by a judicious admixture of aniline (dyes) used as a substitute for paste colors. For the preparation of paste colors themselves aluminin is not indispensable.

Aluminin *a*1 is obtained as a white colored product by decomposing potash alum with carbonate of soda. Thirty-two pounds of potash alum are dissolved in about forty gallons of water, and after this alum liquor has cooled there is added to it a cold solution of soda crystals, containing 30 lb dissolved in 20 gallons of water. When the soda is added to the alum liquor, a copious evolution of carbonic acid takes place, so that the mixing should be carried out slowly in order to avoid excessive effervescence and probable loss of material through the mixture overflowing the sides of the vessel. After the liquors are added together, the vessel containing them is filled full with pure cold water, and allowed to stand at rest for twenty hours, when the precipitation will be complete. The clear liquor is now run off in any convenient way, and the vessel again filled with fresh water, stirred, and allowed to stand till the precipitate deposits. In this way the precipitate is washed with three successive quantities of pure, clean water, and after the last wash-water has been decanted, the remaining white mud is filtered. A tolerably fine linen bag hung inside of a cask whose bottom is perforated with a few holes answers very well as a filter. The neck of the bag is nailed around the rim of the cask. About 60 lb. of thick *a*1 aluminin paste is obtained in this way from the above quantity of alum.

ALUMININ I.—A similar but more copious precipitate is obtained if sulphate of alumina be used instead of potash alum. As sulphate of alumina contains a greater percentage of alumina (Al_2O_3) than alum (in the proportion of 37·38) the quantity of soda required to effect the precipitation is correspondingly greater. The method of precipitating the "aluminin" is exactly the same as above described for *a*1 aluminin, but the yield of paste is greater. Thirty pounds of alum give 60 lb. of well filtered precipitate, while 30 lb. of sulphate of alumina yield 80 lb. of precipitate. If there were not a great difference in the quality of the precipitates obtained from the above two sources of alumina, potash alum would not be used. The precipitate from alum is absolutely white. That from sulphate of alumina always possesses a grayish yellow color, and it is, therefore, not suitable for the preparation of those colors which are characterized by absolute purity of shade.

ALUMININ II is a very cheap but whiter colored precipitate than either of the foregoing. It answers very well for the preparation of many paste colors of ordinary quality, and also as a cheap addition for certain papers, as, for example, in the manufacture of glazed paper. The white precipitate is mixed with a corresponding quantity of *wax soap*, *talc* and glue, and then a suitable anilin color added. Tragacanth (gum) may be employed instead of glue, as it prevents the color (especially red colors) passing through those papers which have not been well sized.

This precipitate is made as follows: 7 lb. of well burnt best white lime are mixed with 1¼ to 2 gallons of hot water in a deep cask, and after the lapse of an hour or so, 20 gallons of cold water are added, and the mixture stirred. The milk of lime is now passed through a fine sieve into a large precipitating vessel, the fine particles being washed from the sieve. The more dilute the milk of lime, the better. To this lime water, which should be perfectly free from sand and grit, a cold solution of 25 lb. sulphate of alumina dissolved in 20 gallons of water is added, with constant stirring, and the precipitating vessel containing the precipitate completely filled with cold water. The precipitation is completed after allowing to stand for twenty-four hours. The clear water is run off and the precipitate repeatedly washed with pure cold water till it is neutral to litmus. The amount of filtered paste obtained is about 100 lb.

ALUMININ III.—If we desire to color papers with weak aniline dyes, difficulties are encountered in laying or smearing it on the paper. To obviate this the solution is mixed with a precipitate not unlike cold starch paste, which thickens the color solution and increases its covering properties without essentially changing the shade.

This precipitate consists of alumina and silica which are precipitated together by the mutual decomposition of silica of soda and alum; 14 lb. of alum or sulphate of alumina (alum yields the whitest product) are dissolved in 20 or 30 gallons of water, and decomposed with 25 lb. of silicate of soda previously mixed with about 20 gallons of water. In practice the silicate of soda is added to the alum solution till it is neutral to litmus. The precipitate is then washed by decantation with water till all the soluble salts are removed, and finally filtered. About 100 lb. of thick gelatinous paste is obtained from these quantities.—*Chem. Tr. Jour.*

THE BLEACHING OF WOOL AND SILK.

ALL who have been engaged in the bleaching of wool or silk by means of sulphur or bisulphite, will have met with grave inconveniences in the washing of the fiber after the bleaching. The most important drawback is that the bleached fiber always exhibits a strong tendency to resume its yellow color sooner or later, especially if it be treated with alkalies, ammonia, soda, etc. If there happens to remain any trace of sulphurous acid on the bleached fiber, as is inevitable, and mixed tissues should be formed, it will easily be observed that the dyed threads lose their color when near those bleached by such a process. Professor Lunge of the Polytechnic School of Zurich has devised a method of meeting these inconveniences. It consists in the bleaching of the fiber either with sulphur, bisulphite, or sulphureted hydrogen in the usual way, then passing the bleached fiber into a bath of peroxide of hydrogen in the following proportions: For 100 kilos. of wool or silk—15 kilos. peroxide of hydrogen, 70 kilos. common water, and 1¼ kilos. silicate of soda. The sulphurous acid contained in excess by the fiber, which causes the inconvenience mentioned, is oxidized by means of this last bath, and transformed into sulphuric acid, which is no longer injurious, and can be completely removed by simple washing.

A New Catalogue of Valuable Papers

Contained in SCIENTIFIC AMERICAN SUPPLEMENT during the past ten years, sent *free of charge* to any address. MUNN & CO., 361 Broadway, New York.

THE SCIENTIFIC AMERICAN

Architects and Builders Edition.

$2.50 a Year. Single Copies, 25 cts.

This is a Special Edition of the SCIENTIFIC AMERICAN, issued monthly—on the first day of the month. Each number contains about forty large quarto pages, equal to about two hundred ordinary book pages, forming, practically, a large and splendid **Magazine of Architecture**, richly adorned with *elegant plates in colors* and with fine engravings, illustrating the most interesting examples of modern Architectural Construction and allied subjects.

A special feature is the presentation in each number of a variety of the latest and best plans for private residences, city and country, including those of very moderate cost as well as the more expensive. Drawings in perspective and in color are given, together with full Plans, Specifications, Costs, Bills of Estimate, and Sheets of Details.

No other building paper contains so many plans, details, and specifications regularly presented as the SCIENTIFIC AMERICAN. Hundreds of dwellings have already been erected on the various plans we have issued during the past year, and many others are in process of construction.

Architects, Builders, and Owners will find this work valuable in furnishing fresh and useful suggestions. All who contemplate building or improving homes, or erecting structures of any kind, have before them in this work an almost *endless series of the latest and best examples* from which to make selections, thus saving time and money.

Many other subjects, including Sewerage, Piping, Lighting, Warming, Ventilating, Decorating, Laying out of Grounds, etc., are illustrated. An extensive Compendium of Manufacturers' Announcements is also given, in which the most reliable and approved Building Materials, Goods, Machines, Tools, and Appliances are described and illustrated, with addresses of the makers, etc.

The fullness, richness, cheapness, and convenience of this work have won for it the **Largest Circulation** of any Architectural publication in the world.

A Catalogue of valuable books on Architecture, Building, Carpentry, Masonry, Heating, Warming, Lighting, Ventilation, and all branches of industry pertaining to the art of Building, is supplied free of charge, sent to any address.

MUNN & CO., Publishers,
361 Broadway, New York.

Building Plans and Specifications.

In connection with the publication of the BUILDING EDITION of the SCIENTIFIC AMERICAN, Messrs. Munn & Co. furnish plans and specifications for buildings of every kind, including Churches, Schools, Stores, Dwellings, Carriage Houses, Barns, etc.

In this work they are assisted by able and experienced architects. Full plans, details, and specifications for the various buildings illustrated in this paper can be supplied.

Those who contemplate building, or who wish to alter, improve, extend, or add to existing buildings, whether wings, porches, bay windows, or attic rooms, are invited to communicate with the undersigned. Our work extends to all parts of the country. Estimates, plans, and drawings promptly prepared. Terms moderate. Address

MUNN & CO., 361 BROADWAY, NEW YORK.

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.00 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and CANVASSERS.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.

PAGE

I. BIOLOGY.—The Migration of the Salmon.—The development of the young salmon and the migrations of the fish, with suggestions as to its preservation by proper game laws.—10 illustrations..... 12611

II. CIVIL ENGINEERING.—Preservative Treatment of Timber.—By OCTAVE CHANUTE.—An important lecture, giving the last views of engineers upon the preservation of railroad ties..... 12600

III. NAVAL ENGINEERING.—The White Star Steamer Teutonic.—Continuation of the elaborate article on the great ocean racer, illustrations of her engines.—6 illustrations..... 12602

IV. PHYSICS.—The Spectroscopic Properties of Dust.—An examination of the influence of dust on the spectrum, with curiously negative results, the inability of dust to become luminous in the path of the electrical discharge shown.—1 illustration..... 12609

V. ELECTRICITY.—The Electromagnet.—By Prof. SILVANUS P. THOMPSON.—Conclusion of Prof. Thompson's exhaustive papers on the electromagnet.—12 illustrations..... 12610

VI. HYDRAULICS.—The Power of Water or Hydraulics Simplified.—By G. D. HISCOX.—The flow from subsurface orifices, the miner's inch, the wet perimeter, and other points in hydraulics, with rules and formulæ.—8 illustrations..... 12606

VII. MECHANICAL ENGINEERING.—A New Mode of Wheel Cutting.—By AMBROSE SWASEY.—A new step in the cutting of gears, with the gear generating and cutting engine of the author described and illustrated.—5 illustrations..... 12605

Improved Tree Cutting Machinery.—Machines for forestry work, including the cutting down of trees by sawing and the dividing of the felled trees into logs.—5 illustrations..... 12606

The Requirements of a Perfect Valve.—A lecture by THOMAS HAWLEY.—The theory of the steam valve discussed from the standpoint of the practical engineer.—Its work and requirements. 12605

VIII. TECHNOLOGY.—"Aluminin."—A new article for the preparation of paste colors for use by the paper manufacturer.—An account of the different grades..... 12614

Manufacture of Sugar in Tablets.—A process of manufacturing sugar in convenient shape, with advantages and details of the process.—4 illustrations..... 12599

Mechanical Maturing of Spirits.—Apparatus for maturing spirits by the effects of compressed air.—1 illustration..... 12601

The Bleaching of Wool and Silk.—The use of peroxide of hydrogen to remove traces of sulphur or sulphurous oxide in silk after bleaching..... 12614

The Cork Industry in Spain.—An interesting account of how cork is collected for shipment..... 12600

The Slot Gas Meter.—Note on a curious novelty..... 12604

Useful Engineering Books

Manufacturers, Agriculturists, Chemists, Engineers, Mechanics, Builders, men of leisure, and professional men, of all classes, need good books in the line of their respective callings. Our post office department permits the transmission of books through the mails at very small cost. A comprehensive catalogue of useful books by different authors, on more than fifty different subjects, has recently been published, for free circulation, at the office of this paper. Subjects classified with names of author. Persons desiring a copy have only to ask for it, and it will be mailed to them. Address,

MUNN & CO., 361 Broadway, New York.

PATENTS.

In connection with the **Scientific American**, Messrs. MUNN & Co. are solicitors of American and Foreign Patents, have had 42 years' experience, and now have the largest establishment in the world. Patents are obtained on the best terms.

A special notice is made in the **Scientific American** of all inventions patented through this Agency, with the name and residence of the Patentee. By the immense circulation thus given, public attention is directed to the merits of the new patent, and sales or introduction often easily effected.

Any person who has made a new discovery or invention can ascertain, free of charge, whether a patent can probably be obtained, by writing to MUNN & Co.

We also send free our Hand Book about the Patent Laws, Patents, Caveats, Trade Marks, their costs and how procured. Address

MUNN & CO.,
361 Broadway, New York.

Branch Office, 622 and 624 F St., Washington, D. C.